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The Sensitivity of Complex Photochemical Model Estimates to Detail in Input Information
Appendix A: A Compilation of Simulation Results

Systems Applications, Inc.
San Rafael, CA

Prepared for

Environmental Protection Agency
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This report summarizes results of 22 sensitivity tests in which the impact of degrading the data base in the Los Angeles area on predictions of a photochemical grid model (Urban Airshed Model) is tested. Input tested includes upper air and surface meteorological and air quality data, initial and boundary conditions, speciation of organic pollutants, temporal and areal resolution of emissions, model grid square size, and vertical resolution available in the model.

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Appendix A

COMPILATION OF SIMULATION RESULTS

1. OVERVIEW

This appendix presents and discusses the results of twenty-two SAI Airshed Model sensitivity simulations. A general description of the sensitivity simulations is presented in section 2. Various measures, presented in section 3, are used to quantify the sensitivity of model ozone calculations to variations in input parameters and data. These measures include ozone concentration level deviations, temporal and spatial correlations, comparison of maximum ozone levels, dosage, and so on. In Section 4, the most significant changes in model predictions for each simulation (compared with the base cases) are discussed under the heading General Sensitivity Measures.

Section 5 discusses how a reduction in available data is manifested in perturbations to one or several input variables to the simulation model. For example, the perturbation in hourly average mixing depths resulting from the use of a single upper air sounding station is analyzed. Altered mixing depths lead, in turn, to changes (from the base case) in the temporal and spatial distributions of model ozone calculations.

2. GENERIC DESCRIPTION OF SENSITIVITY RUNS

The 22 sensitivity runs performed in this study may be grouped into the following general categories:

- Meteorology
- Air Quality
- Emissions
- Model Structure.

Table A-1 describes each simulation briefly. A more detailed description of each sensitivity case is given in the main report "Sensitivity of Complex Photochemical Model Estimates to the Detail in Input Information," Chapter III. The sensitivity runs are discussed in section 4 in the order shown in table A-1.

3. MEASURES FOR ASCERTAINING MODEL SENSITIVITY

An important step in quantifying model sensitivity is the definition of specific measures. Several useful measures include the following:

> Signed deviation.

> Absolute deviation.

> Temporal correlation.

> Spatial correlation.

> Overall maximum ozone level.

> Maximum ozone statistics (peak level difference, peak time lag).

> Dosage.

In addition, isopleths of maximum ozone deviation and ozone profiles at air quality monitoring stations are developed to provide information on the spatial and temporal perturbations in the model predictions.

Note that these measures, to be defined more precisely in the following subsections, are quite similar to those used to evaluate model performance in simulating the June and August oxidant episodes.

a. Signed Deviation

The signed deviation is calculated as follows:

$$\frac{1}{N'} \sum_{j=1}^{N'} \frac{1}{N} \sum_{i=1}^{N} \frac{C_{s,i,j} - C_{b,i,j}}{C_{b,i,j}} , \qquad \text{(A-1)}$$

where $C_{s,i,j}$ and $C_{b,i,j}$ are the ozone concentrations for the sensitivity case and the base case, respectively, at station (or grid cell) i and for

TABLE A-1. DESCRIPTIONS OF THE AIRSHED MODEL SENSITIVITY SIMULATIONS

Run Number	Description	Characteristics of the Base Case		Characteristics of the Sensitivity Run
1	74 upper air	Upper level wind	Radiosondes at Riverside (0600 PST), El Monte (0700, 1330), LAX (0630,1230), Pt. Mugu (0400, 1000, 1600 PST) and San Nicholas Island (1400 PST)	26 June 1974 wind fields and mixing depths based on 0700 and 1330 El Monte radiosondes
		Mixing depths	Acoustic sounder at El Monte	
			Aircraft spiral at Riverside (0600 PST)	
			Radiosondes at LAX (0630, 1230 PST), El Monte (0700, 1300 PST), Pt. Mugu (0400, 1000, 1600 PST), and San Nicholas Island (1400 PST)	
2	75 upper air meteorological data	Upper level winds	Radiosondes at LAX (1130 PST), El Monte (0610,1230 PST), Pt. Mugu (0350, 1004, and 1615 PST), and San Nicholas Island (1405 PST)	4 August 1975 wind fields and mixing depths based on 0610 and 1230 El Monte radiosondes
			Pibals at Burbank (1940 PST) and San Bernardino (0345 and 1030 PST)	
		Mixing depths	Aircraft spiral at Riverside (0300 PST)	
			Radiosondes at LAX (0630, 1030 PST), El Monte (0610, 1230 PST), Pt. Mugu (0360, 1004, 1615 PST), and San Nicholas Island, (1405 PST)	
3	74 surface and upper air meteorological data	Surface winds	60 surface wind monitoring stations	26 June 1974 wind fields and mixing depths based on 0700 and 1330 El Monte radiosondes and surface winds and temperatures at ten monitoring stations*
		Upper level winds	Radiosondes at Riverside (0600 PST), El Monte (0700, 1330), LAX (0630, 1230), Pt. Mugu (0400, 1000, 1600 PST) and San Nicholas Island (1400 PST)	
		Mixing depths	Acoustic sounder at El Monte aircraft spiral at Riverside	
			Radiosordes at LAX (0630, 1230 PST), El Monte (0700, 1300 PST), Pt. Mugu (0400, 1000, 1600 PST), and San Nicholas Island (1400 PST)	
		Surface temperatures	Temperatures at several stations	

TABLE A-1 (Continued)

4	75 surface and upper air meteorological data	Surface winds	56 surface wind monitoring stations	4 August 1975 wind fields and mixing depths based on 0610 and 1230 El Monte radiosondes and surface winds and temperatures at ten monitoring stations
		Upper level winds	Radiosondes at LAX (1130 PST), El Monte (0610, 1230 PST), Pt. Mugu (0350, 1004, and 1615 PST), and San Nicholas Island (1405 PST)	
			Pibals at Burbank (1940 PST) and San Bernardino (0345 and 1030 PST)	
		Mixing depths	Aircraft spiral at Riverside (0300 PST)	
			Radiosondes at LAX (0630, 1030 PST), El Monte (0610, 1230 PST), Pt. Mugu (0350, 1004, 1615 PST) and San Nicholas Island (1405 PST)	
		Surface temperatures	Temperatures at 15 stations	
5.1	Ground level initial and boundary conditions		Initial and boundary conditions based on synthesis of data from 39 air quality monitoring stations	26 June 1974 initial and boundary conditions based on 10 surface monitoring stations
5.2	74 reduced meteorological and air quality data		See descriptions of runs 3 and 5.1 above	26 June 1974 wind fields, mixing depths, initial conditions, and boundary conditions based on 0700 and 1300 El Monte radiosondes and surface winds, temperatures, and pollutant concentration measurements at ten monitoring stations
6	Upper air quality data		Upper air concentration profiles assumed to decrease with height to assumed background values	26 June 1974 simulation with layer of precursor material aloft, estimated from 3-D gradient study profiles
7	75 clean air boundary conditions		Boundary conditions based on synthesis of data from 48 air quality monitoring stations	4 August 1975 simulation with less precursor material aloft; clean air boundary conditions
8	74 clean air boundary conditions		Boundary conditions based on synthesis of data from 39 air quality monitoring stations	26 June 1974 simulation with less precursor material aloft; clean air boundary conditions
9	74 assumed RHC/NO_x ratio		Reactive hydrocarbon concentrations based on empirical relationship derived from ambient RHC measurements by Mayersohn et al. (1975) in 1974	26 June 1974 simulation with initial hydrocarbon concentrations based on an assumed aerometric hydrocarbon/NO_x ratio of 7; clean air boundary conditions
10	75 assumed RHC/NO_x ratio		Reactive hydrocarbon concentrations based on empirical relationship derived from ambient RHC measurements by Mayersohn et al. (1976) in 1975	4 August 1975 simulation with initial hydrocarbon concentrations based on an assumed aerometric hydrocarbon/NO_x ratio of 7; clean air boundary conditions
11	74 hydrocarbon emissions speciation		Volatile organic compound speciation based on research by KVB Engineering, Incorporated, under EPA Contract No. 68-02-3209	26 June 1974 reactive hydrocarbon emissions split according to an assumed composite urban mix

TABLE A-1 (Concluded)

12	75 hydrocarbon emission speciation	Volatile organic compound speciation based on research by KVB Engineering, Incorporated, under EPA Contract No. 68-02-3209	4 August 1975 reactive hydrocarbon emissions split according to an assumed composite urban mix
13	74 mobile source	Emission estimates derived from the LARTS transportation model and the ARB DTIM emission model	26 June 1974 mobile source emissions based on outdated transportation model and emission simulator
14	74 gas sales	Emission estimates derived from the LARTS transportation model and the ARB DTIM emission model	26 June 1974 mobile source emissions based on estimated vehicle fuel economy, areawide fuel sales, ensemble emission factors, and composite urban vehicle mix
15	75 gas sales	Emission estimates derived from the LARTS transportation model and the ARB DTIM emission model	4 August 1975 mobile source emissions based on estimated vehicle fuel economy, areawide fuel sales, ensemble emission factors, and composite urban vehicle mix
16	Point source	Day-specific, hourly-average emission rates for power plants obtained directly from the utilities	26 June 1974 power plant emissions based on annual average emission rates and average diurnal generating profile
17	74 area source	Detailed, distributed area source inventory developed by the South Coast Air Quality Management District (SCAQMD, 1978)	26 June 1974 distributed area sources spatially allocated according to the demographic distribution
18	75 area source	Detailed, distributed area source inventory developed by the South Coast Air Quality Management District (SCAQMD, 1978)	4 August 1975 distributed area sources spatially allocated according to the demographic distribution
19	Temporal resolution	Detailed, distributed area source inventory developed by the South Coast Air Quality Management District (SCAQMD, 1978)	26 June 1974 area sources temporally resolved according to assumed generic diurnal profiles
20	10 km	Horizontal grid resolution of 5 km	26 June 1974 simulation based on a 10-km horizontal grid mesh
21	two-layer model	Four levels of grid cells	26 June 1974 simulation with one layer below the inversion and one above
22	one-layer model	Four levels of grid cells	26 June 1974 simulation with one layer below the inversion

---

* The ten stations are: downtown Los Angeles, Azusa, Burbank, Long Beach, Anaheim, San Bernardino, Reseda, Lennox, Prado Park, and Upland.

the hour j; N is the number of stations (or grid cells), and N' the number of simulation hours.

Two signed deviations are calculated. The signed deviation is computed for the ozone levels at the air quality monitoring stations and for the ozone levels in all ground-level grid cells (grid cells in mountainous areas and over the Pacific ocean are not included).

b. Absolute Deviation

The absolute deviation in ozone levels is computed as follows:

$$\frac{1}{N'} \sum_{j=1}^{N'} \frac{1}{N} \sum_{i=1}^{N} \frac{\left|C_{s,i,j} - C_{b,i,j}\right|}{C_{b,i,j}} \quad . \qquad \text{(A-2)}$$

Absolute deviation in ozone concentration levels (i.e., base case vs. simulation) is computed for the air quality monitoring stations and for the ground-level grid cells.

c. Temporal Correlation

The temporal correlation refers to the "timing" of the ozone concentration levels computed by both the sensitivity case and the base case at a specified station or in a specified grid cell. The temporal correlation at a given location is determined from the hourly concentrations predicted by the sensitivity case and the base case at a given location j. A correlation coefficient is then calculated for each station according to routine statistics. These correlation coefficients are normalized with respect to the "perfect correlation line" (Hoel, 1962) by performing the following change of variable:

$$\phi_j = \frac{1}{2} \ln \frac{1 + r_j}{1 - r_j} \quad , \qquad \text{(A-3)}$$

where r_j is the computed correlation coefficient for the station or grid cell j. The mean value of the ϕ_j's is computed for all locations:

$$\Phi = \frac{1}{N} \sum_{j=1}^{N} \phi_j \quad , \qquad \text{(A-4)}$$

where N is the number of stations or grid cells. Because the values of ϕ_j are approximately normally distributed (Hayes, 1978), the average temporal correlation coefficient ρ is evaluated from the following formula:

$$\bar{\Phi} = \frac{1}{2} \ln \frac{1 + \rho}{1 - \rho} \quad . \tag{A-5}$$

Thus, the average temporal correlation coefficient is:

$$\rho = \frac{\exp\,(2\,\bar{\Phi}) - 1}{\exp\,(2\,\bar{\Phi}) + 1} \quad . \tag{A-6}$$

The temporal correlation is computed both from station and grid statistics. Perfect correlations exists when $\rho = 1.0$.

d. Spatial Correlation

The spatial correlation between the concentration fields calculated in a sensitivity run and those calculated in the base case is another useful measure. Hourly correlation coefficients can be computed by considering the values of concentrations predicted by the sensitivity case and by the corresponding base case for each station or grid cell. Then, the estimation of the average spatial correlation coefficient follows the procedure described above for the temporal correlation coefficient. Two spatial correlation coefficients are computed from station statistics and from grid statistics, respectively.

These sensitivity measures (signed deviation, absolute deviation, temporal correlation, and spatial correlation) may be evaluated as a function of concentration level. They are computed in this study for ozone levels $>$ 12 pphm (the National Ambient Air Quality Standard) and for ozone levels $>$ 20 pphm.

e. Overall Maximum Ozone Level

The maximum ground level ozone concentration in the basin is computed for the sensitivity case and the base case from station and grid statistics. The overall maximum ozone level and the corresponding location (station or grid) provide an additional measure of model sensitivity.

f. Maximum Ozone Statistics

The maximum ozone levels occurring at each monitoring station may be computed for both the sensitivity and the base case. The peak level normalized difference is defined as follows:

$$\frac{1}{N} \sum_{i=1}^{N} \left| \frac{C^{*}_{s,i} - C^{*}_{b,i}}{C^{*}_{b,i}} \right| , \qquad \text{(A-7)}$$

where $C^{*}_{s,i}$ and $C^{*}_{b,i}$ are the maximum ozone concentrations for the sensitivity case and the base case, respectively, at Station i. This measure is computed for the 23 air quality monitoring stations within the computational grid. Coastal stations are principally affected by boundary conditions and local emissions since the wind flow in both base cases is westerly for the majority of the simulation time. Accordingly, these stations are removed from calculation of the maximum ozone statistics.* Peak level normalized differences are computed for the remaining 16 downwind stations.

The average peak time lag for maximum ozone level occurrence is evaluated as follows:

$$\frac{1}{N} \sum_{i=1}^{N} \left| T_s - T_b \right| , \qquad \text{(A-8)}$$

where T_s and T_b are the time of the maximum ozone level in the sensitivity case and in the base case, respectively. This measure is evaluated for the 23 stations and for the 16 downwind stations.

g. Dosage

Dosage measures were based on the gridded area with simulated ozone levels above 20 pphm. Dosage is obtained by adding the number of grid cells with ozone levels above 20 pphm over the entire 19-hour simulation period. This measure is computed for both the base cases and sensitivity cases. The normalized difference of dosages provides an additional measure of the model sensitivity:

---

* The coastal stations that are not included in this analysis are Costa Mesa, El Toro, Laguna Beach, Long Beach, Los Alamitos, Redondo Beach, and West Los Angeles.

$$\text{Normalized difference} = \frac{\text{Dosage of sensitivity case - Dosage of base case}}{\text{Dosage of base case}} .$$

h. Isopleths of Maximum Ozone Deviation

Quantification of the spatial changes in predicted ozone levels aids in the interpretation of the sensitivity results. Isopleths of the deviations in maximum ozone concentrations are presented. It should be noted that maximum ozone concentrations may occur at the same location at different times. This isopleth presentation provides useful information about the magnitude and location of changes in ozone concentrations.

i. Ozone Profiles at Air Quality Monitoring Stations

Comparison of calculated and observed ozone concentrations at various air quality monitoring stations is another useful measure of model sensitivity; accordingly, the time-varying ozone concentrations at the monitoring stations are compared for the sensitivity and base cases. This provides information on the temporal variation and magnitude of the perturbations in ozone concentrations at various locations throughout the basin.

To keep the display of simulation results to a manageable level, 6 stations were selected from the 23 monitoring sites for detailed discussion of the sensitivity results. The six monitoring locations are:

- > Anaheim
- > La Habra
- > Lynwood
- > Pasadena
- > San Bernardino
- > Upland.

These stations were chosen because they typically present discernible deviations in ozone concentration levels between the sensitivity and base cases. Moreover, the stations are aligned with the windflow trajectory that carries the photochemical plume eastward across the basin. Where indicated, additional monitoring stations that present interesting features in the diurnal ozone profiles will be discussed in some sensitivity studies.

j. Summary of Sensitivity Measures

These sensitivity measures are considered in the following discussion:

- Signed deviation, absolute deviation, temporal correlation, and spatial correlation of ozone levels for the following selected station locations and grid cells.
    - Stations with ozone levels above 12 pphm.
    - Stations with ozone levels above 20 pphm.
    - Grids with ozone levels above 12 pphm.
    - Grids with ozone levels above 20 pphm.
- Overall maximum ozone level predicted by the sensitivity case and the base case and the corresponding location of occurrence for:
    - Station statistics
    - Grid statistics
- Ozone peak level normalized differences and peak time lag for:
    - All 23 stations
    - 16 downwind stations.
- Dosages of the sensitivity case and of the base case, and the corresponding normalized difference.
- Isopleths of maximum ozone deviations between the sensitivity case and the base case.
- Ozone concentration profiles predicted by the sensitivity case and the corresponding base case at some monitoring stations.

4. SIMULATION RESULTS

a. Model Sensitivity to Upper Air Meteorological Data--Simulation of 26 June 1974

In this sensitivity study, the number of upper air meteorological stations has been reduced. This reduction affects the estimation of the mixing heights computation of the wind field, and estimates of eddy diffusivity coefficients and upper air thermal structure.

1) General Sensitivity Measures

Some measures of the general sensitivity of the model are presented in table A-2. There is a strong effect on the predicted ozone levels from reduction in upper air meteorological data. Overall, lower ozone levels are predicted and the deviation from the base case is larger for higher ozone levels. The values of the temporal and spatial correlation coefficients are low (less than 0.622), which suggests that the temporal and spatial features of the model have been notably perturbed. No major discrepancy appears between the station and grid statistics.

For the maximum ozone-level comparisons, similar results are obtained with all stations and with the downwind stations. This finding suggests that ozone predictions have been affected throughout the basin. An important reduction of the area with ozone levels above 20 pphm has occurred; this reduction corresponds to the important reduction in ozone levels that appears in the signed deviation sensitivity measure.

2) Sensitivity of Model Input Variables to Input Data

The model input variables affected by changes in the upper air meteorological data are the mixing height, the wind field (wind velocity and wind direction in the three-dimensional grid model), and the eddy diffusivities.

The differences in mixing heights between the sensitivity case and the base case between the hours of 4 and 5, 11 and 12, and 15 and 16, L.S.T. are shown in figure A-1. The mixing height is higher in the center of the basin, from Lynwood to Riverside, in the early morning. This pattern moves eastward, and by 10 a.m. the mixing height is lower in the sensitivity case than in the base case, throughout the basin. This situation persists until 15 L.S.T. At about 15 L.S.T., the mixing height

TABLE A-2. GENERAL SENSITIVITY MEASURES--CASE 1

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	O_3 > 12 pphm	O_3 > 20 pphm	O_3 > 12 pphm	O_3 > 20 pphm
Signed deviation	-0.177	-0.342	-0.229	-0.366
Absolute deviation	0.300	0.366	0.329	0.378
Temporal correlation	0.023	-0.009	0.134	0.012
Spatial correlation	0.622	-0.133	0.376	0.403

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	0.718	0.814
Peak level (pphm):		
Sensitivity case	25.5	31.6
Base case	35.5	38.9
Corresponding locations:		
Sensitivity case	Upland	30 - 16
Base case	Azusa	33 - 14

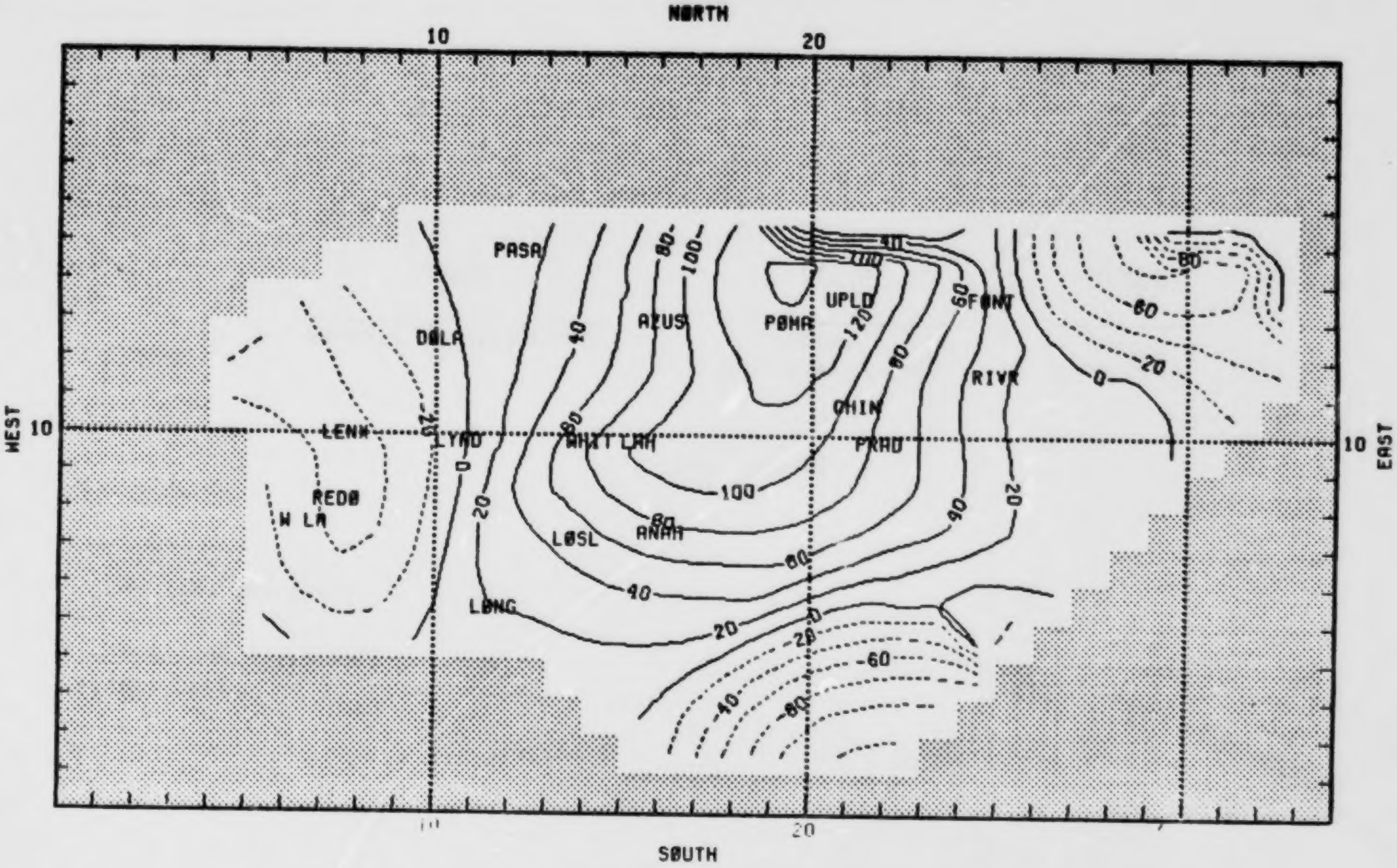
TABLE A-2 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.253	0.258
Peak time lag (hrs)	1.77	1.87

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
-0.402	5,975	10,000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ANAH
LØNG
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20
40
60
80
100
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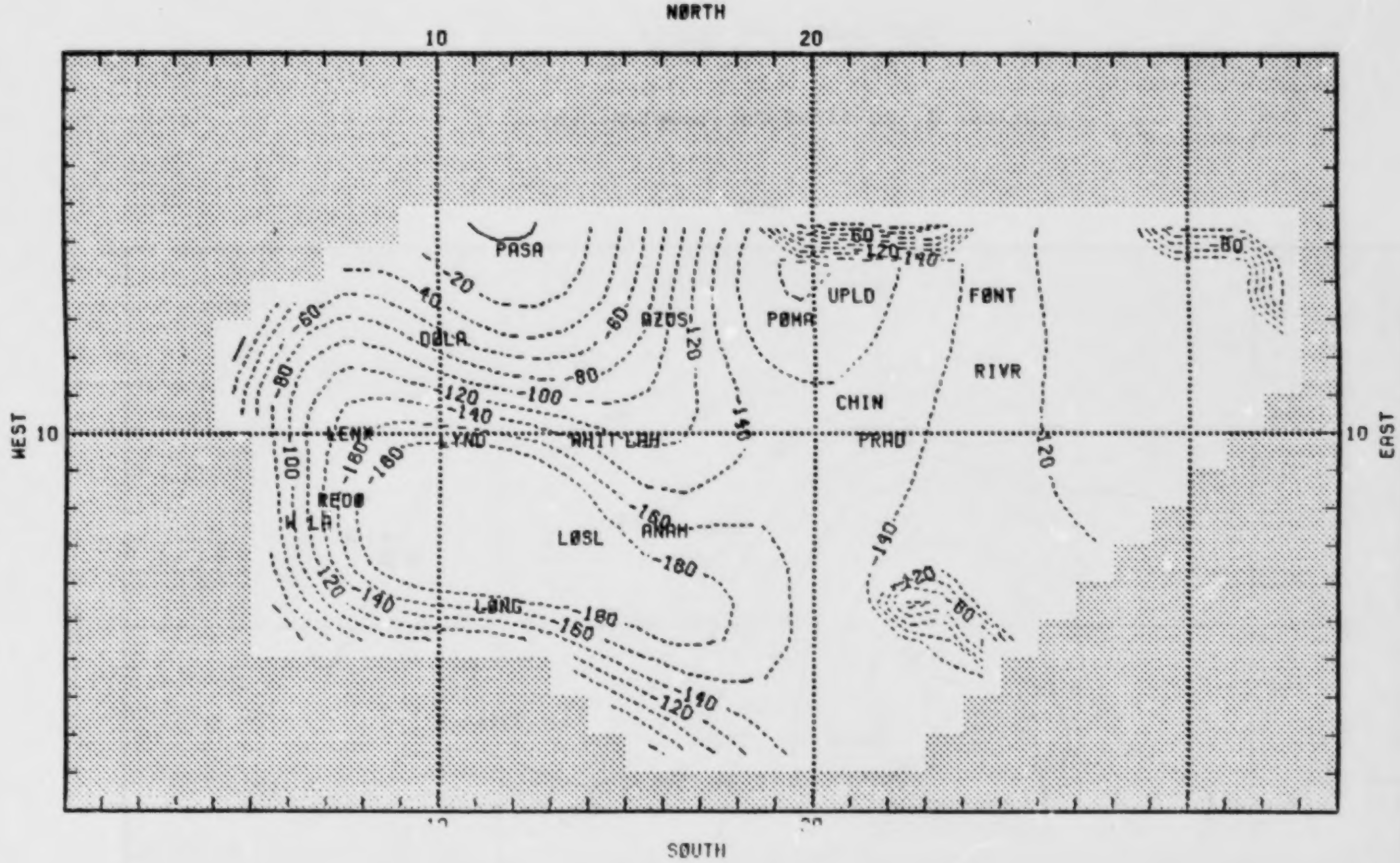
-60
-80

(a) Between the Hours of 4 and 5 LST

FIGURE A-1. MIXING HEIGHT DIFFERENCE (m): CASE 1--BASE CASE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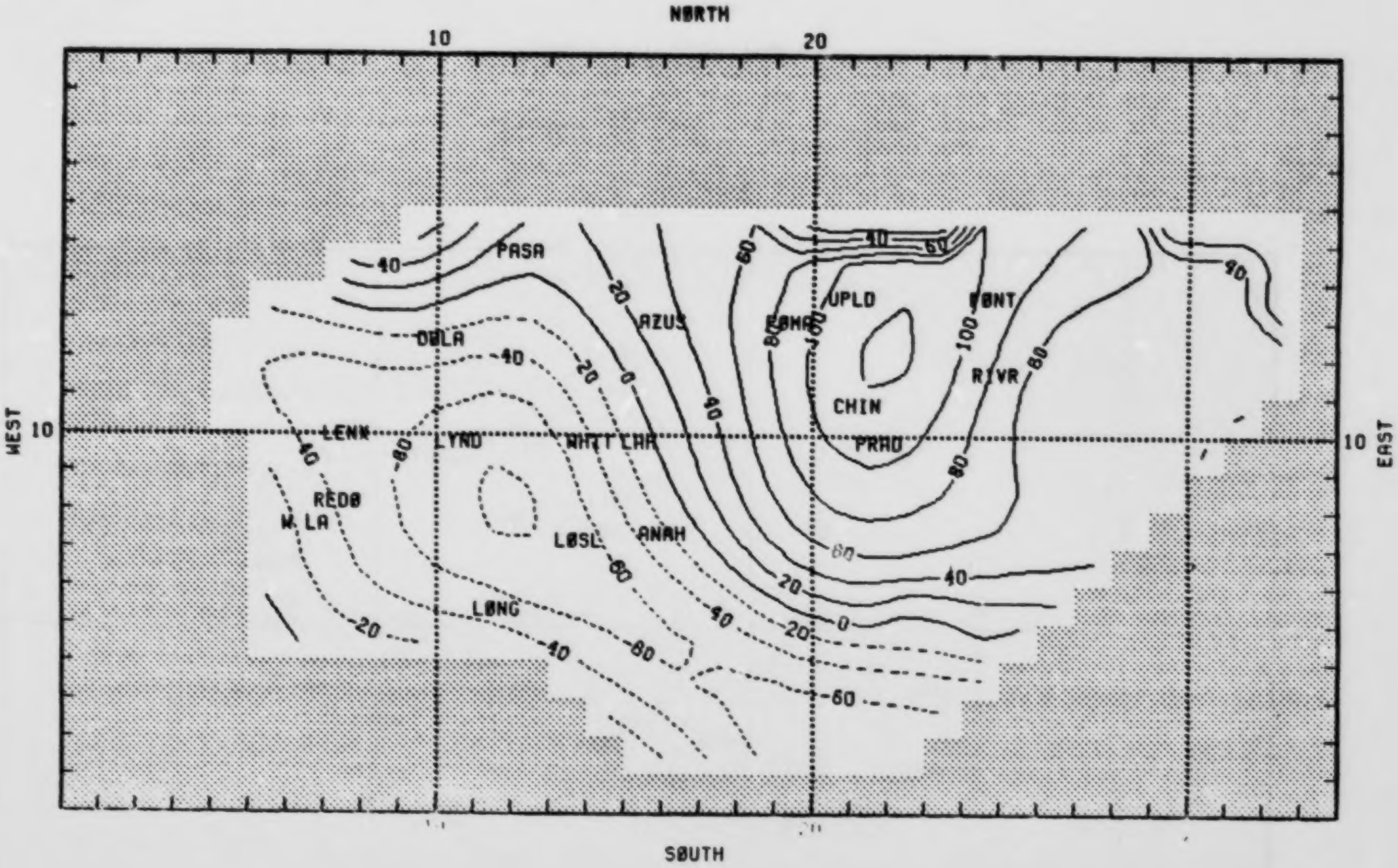
(b) Between the Hours of 11 and 12 LST

FIGURE A-1 (Continued)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ANAH
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-60
-80
60
80
100

(c) Between the Hours of 15 and 16 LST

FIGURE A-1 (Concluded)

is higher around Upland and Chino for the sensitivity case. This pattern extends to the whole basin in two hours.

From these results, one would expect higher ozone concentrations in most of the basin because of lower mixing heights, except in the eastern part of the basin where the morning pattern of higher mixing height persists until 10 L.S.T. The opposite effect is predicted, however. Higher mixing depths in the early morning will lead to greater dispersion of the primary pollutants. However, higher mixing heights do not occur in the western part of the basin (where upwind emission sources are located) long enough to account totally for the lower ozone levels, therefore some other factor must be considered.

The ground-level wind field is shown in figure A-2 for the base case (26 June 1974) and for the sensitivity case, between the hours of 4 and 5, 8 and 9, 11 and 12, and 18 and 19 L.S.T. The wind field is very sensitive to upper air meteorological data. In the base case, one observes southerly winds at 8 L.S.T. that evolve to southwesterly winds around 11 L.S.T. In the sensitivity case, winds are southwesterly at 8 L.S.T. (about 45° difference from the base case) and become more southerly around 11 L.S.T.

In the southeastern part of the basin, between the Santa Ana mountains and the San Jacinto mountains, the wind field is quite different: in the base case there is a wind flow in the valley towards the southeast, whereas in the sensitivity case southerly winds dominate the whole wind field. This should lead to higher pollution levels in the downwind regions for the sensitivity case.

Wind velocities appear slightly higher in the sensitivity case in the morning (e.g., 8 to 9 L.S.T.); however, the difference seems insufficient to account for the large deviations in ozone levels.

The air parcels that reach Pasadena, Azuza, and Prado around noon* differ between the base case and the sensitivity case. Different emissions of primary pollutants will have been injected into the air parcel reaching the source monitoring site in both the sensitivity case and the base case. Air parcel trajectories arriving at Pasadena, Azuza, and Prado at 12 L.S.T. are shown in figure A-3 for the base case and the sensivitity case. A deviation of one or two grid cells may occur at certain hours along the path of these air parcels. This results in different levels of precursors. For instance, concentrations of NO, NO_2

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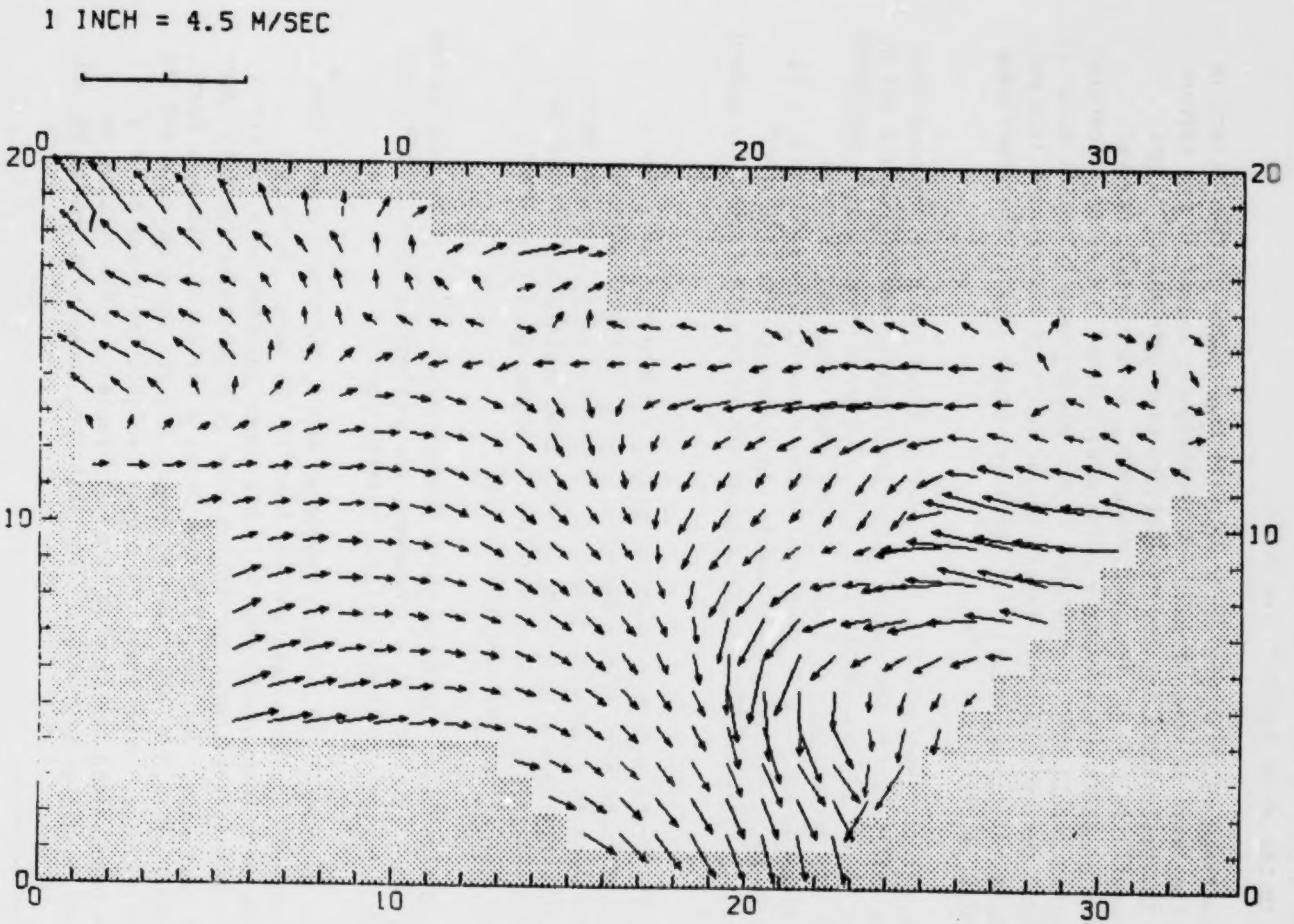
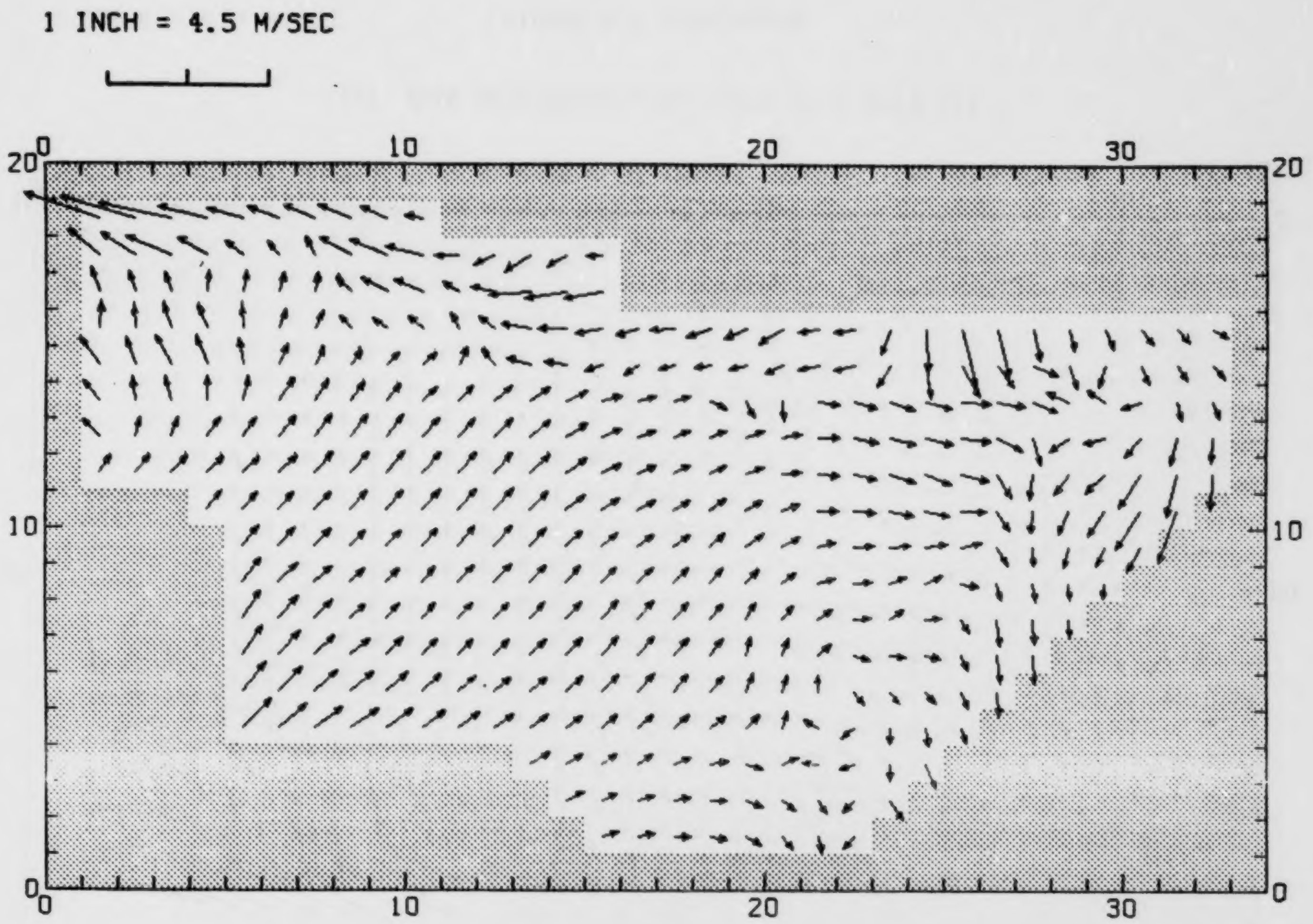
* This corresponds approximately to the ozone peak time, except for the base case at Prado.



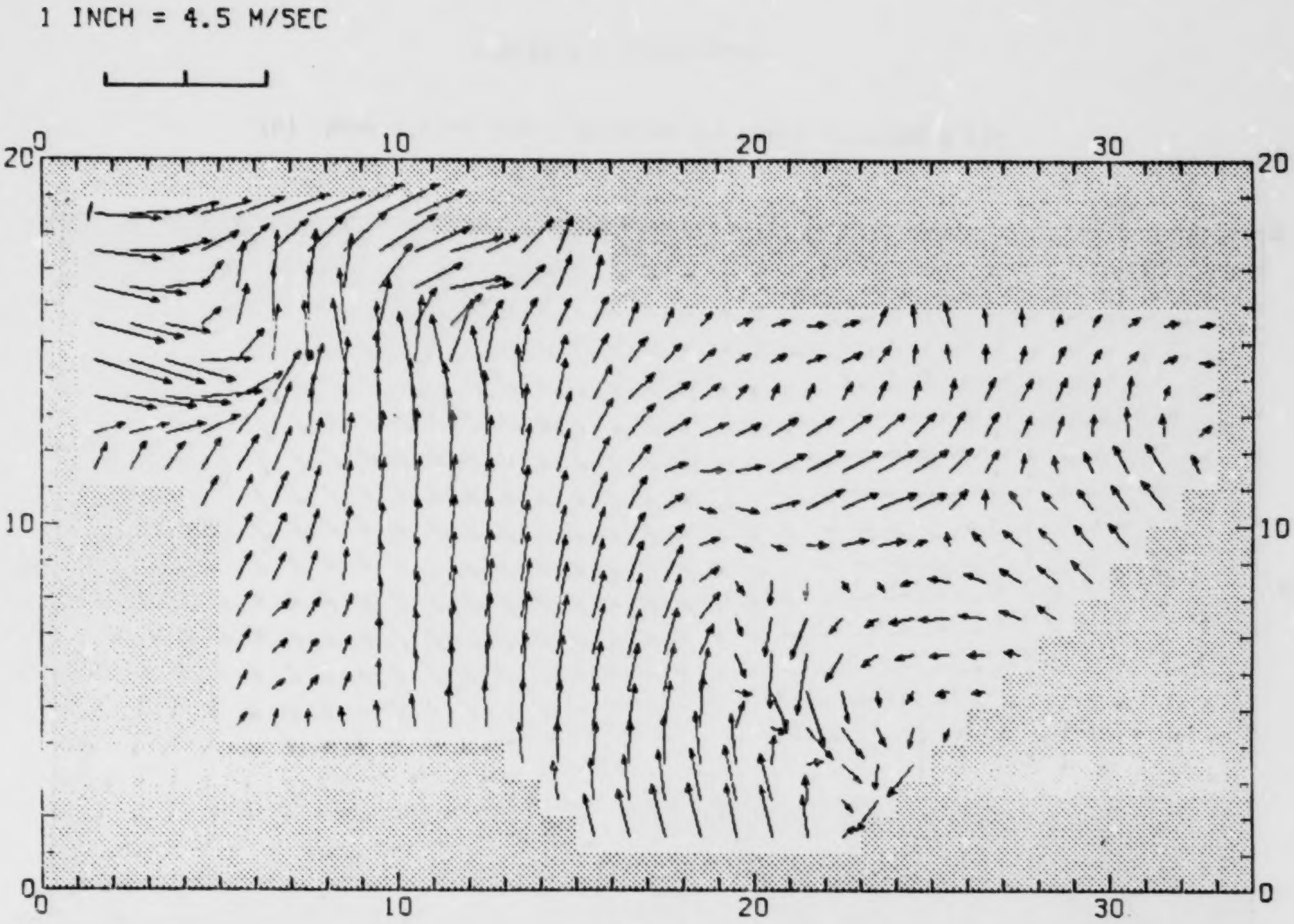
(a) Base Case Between the Hours of 4 and 5 LST

FIGURE A-2. WIND FIELD AT GROUND LEVEL, 26 JUNE 1974



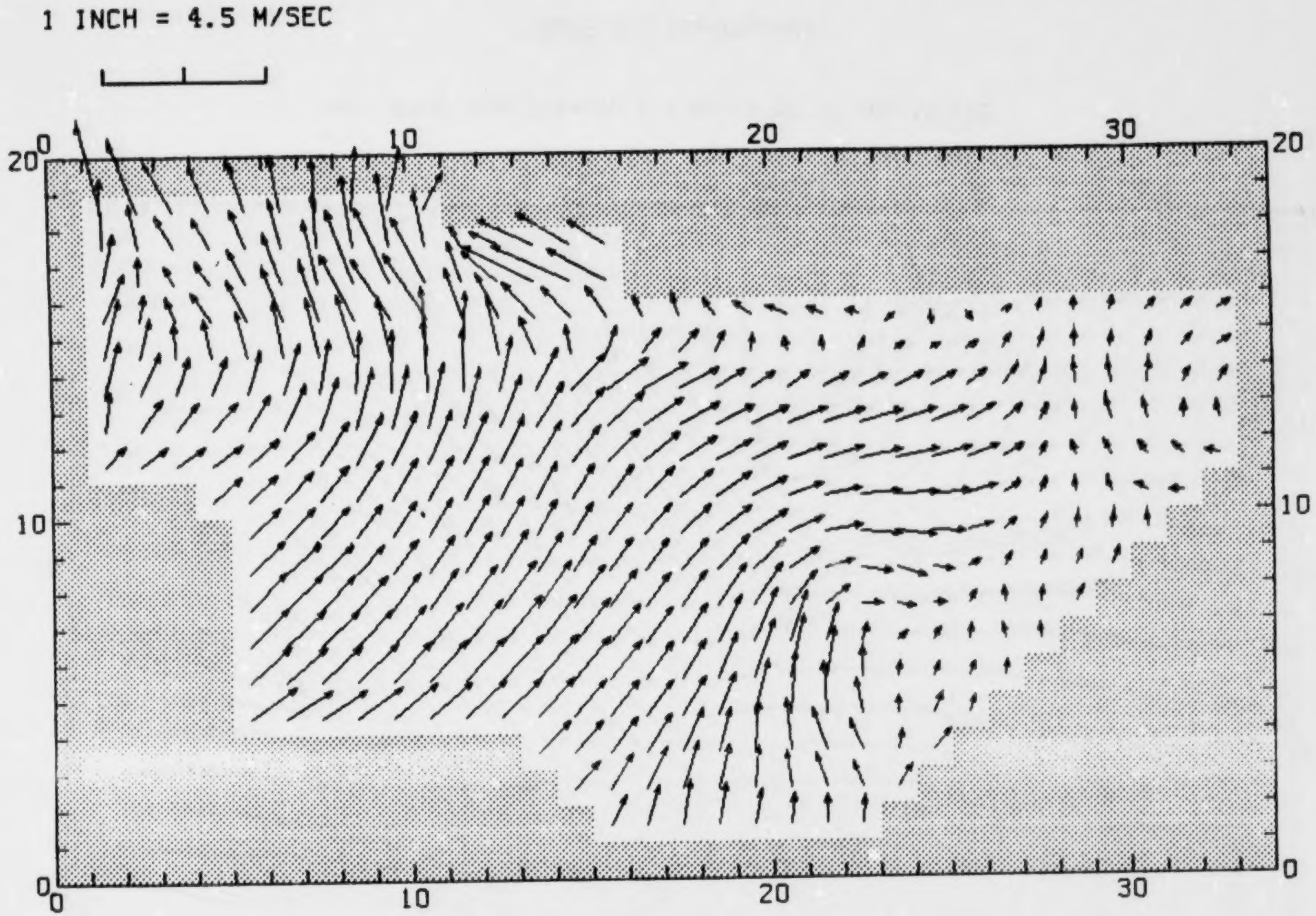
(b) Sensitivity Case 1 Between the Hours of 4 and 5 LST

FIGURE A-2 (Continued)



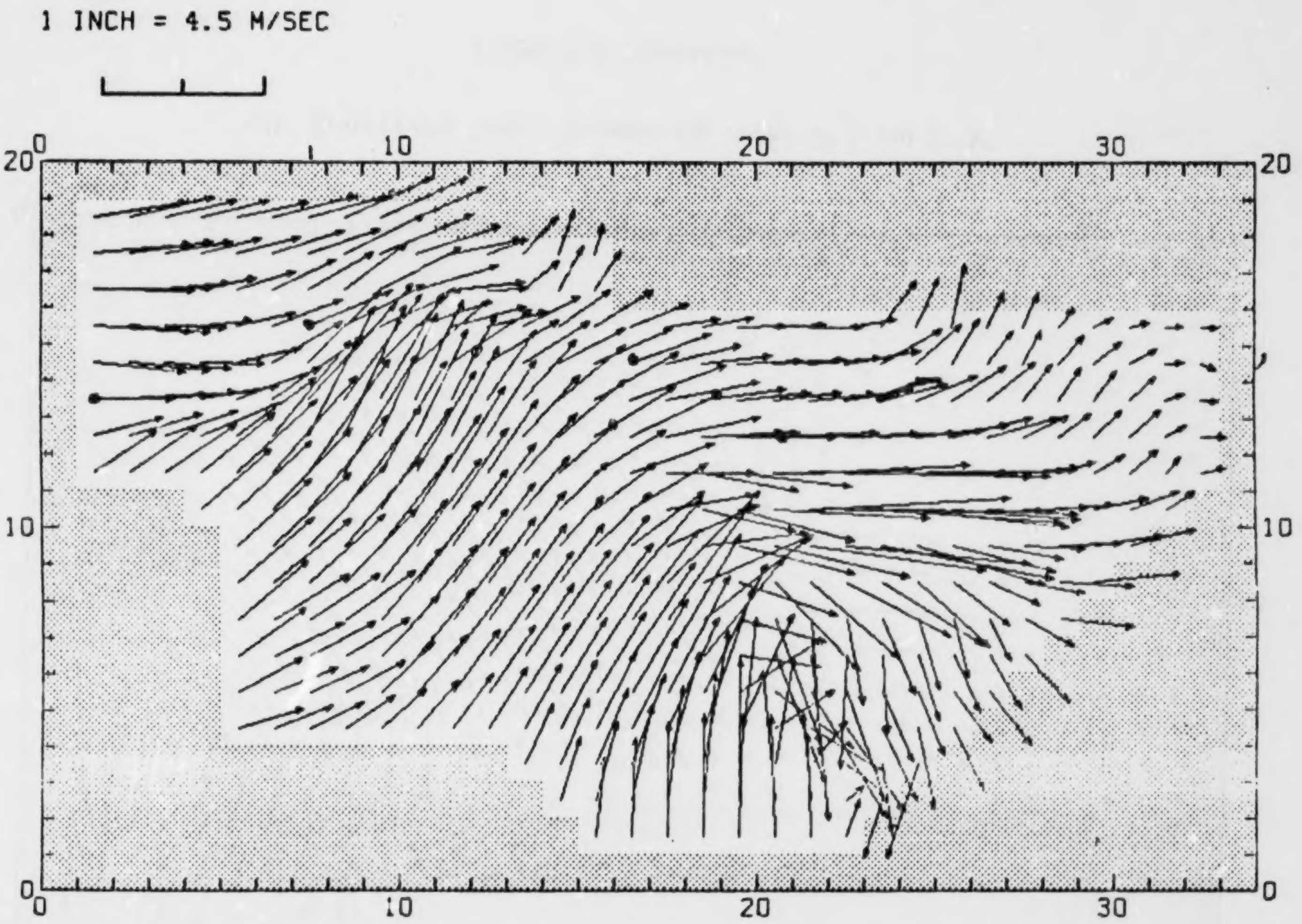
(c) Base Case Between the Hours of 8 and 9 LST

FIGURE A-2 (Continued)



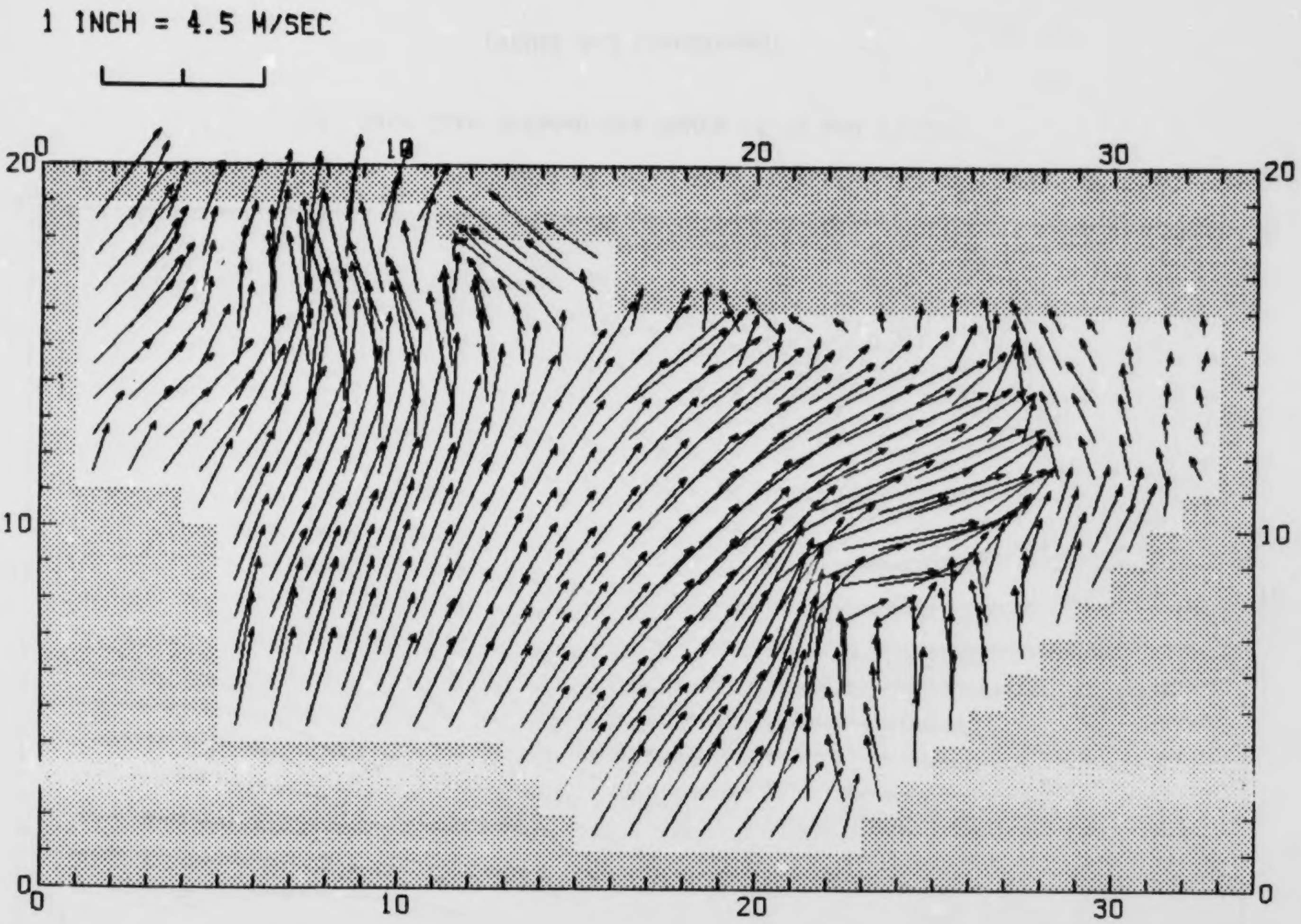
(d) Sensitivity Case 1 Between the Hours of 8 and 9 LST

FIGURE A-2 (Continued)



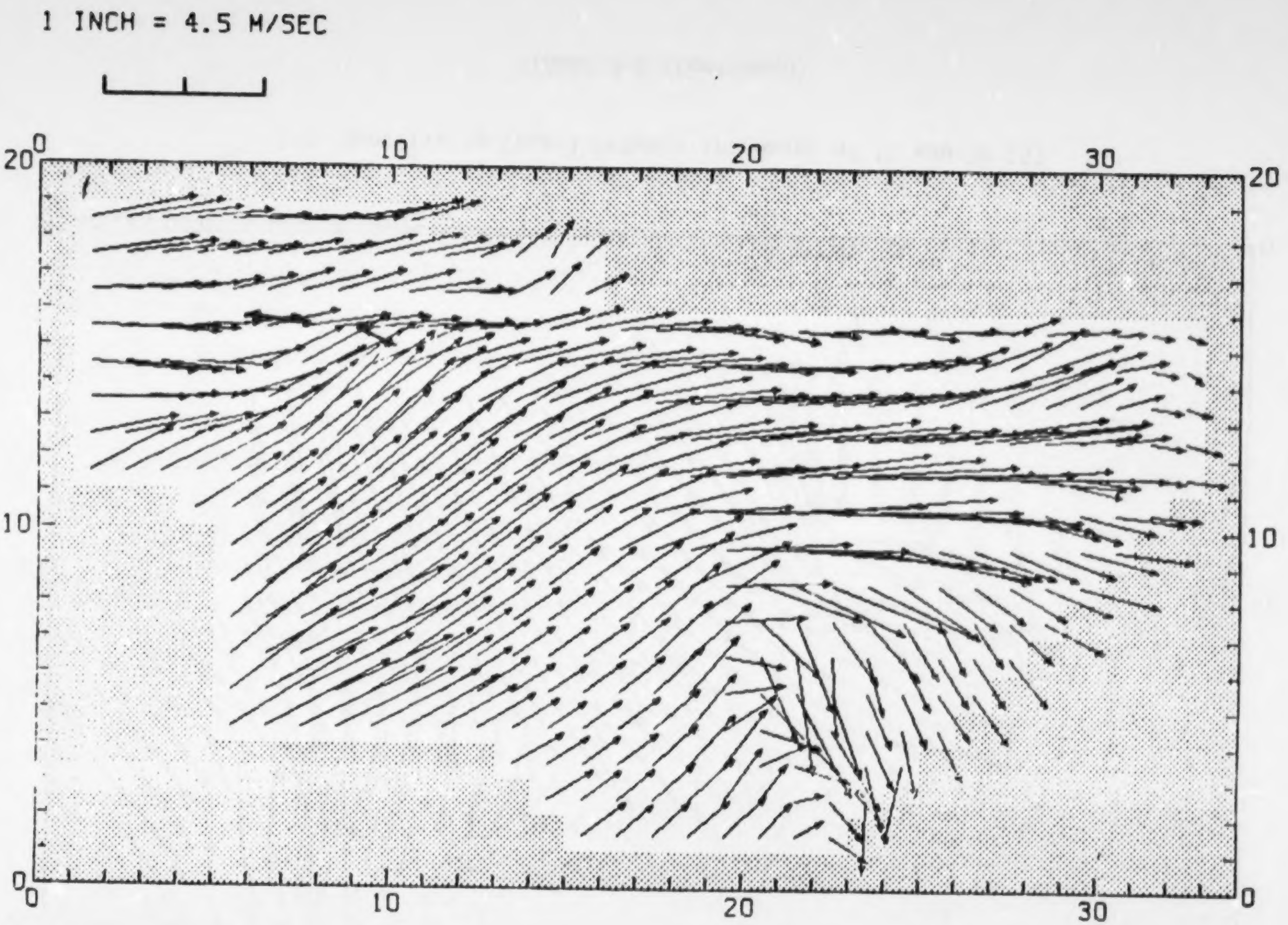
(e) Base Case Between the Hours of 11 and 12 LST

FIGURE A-2 (Continued)



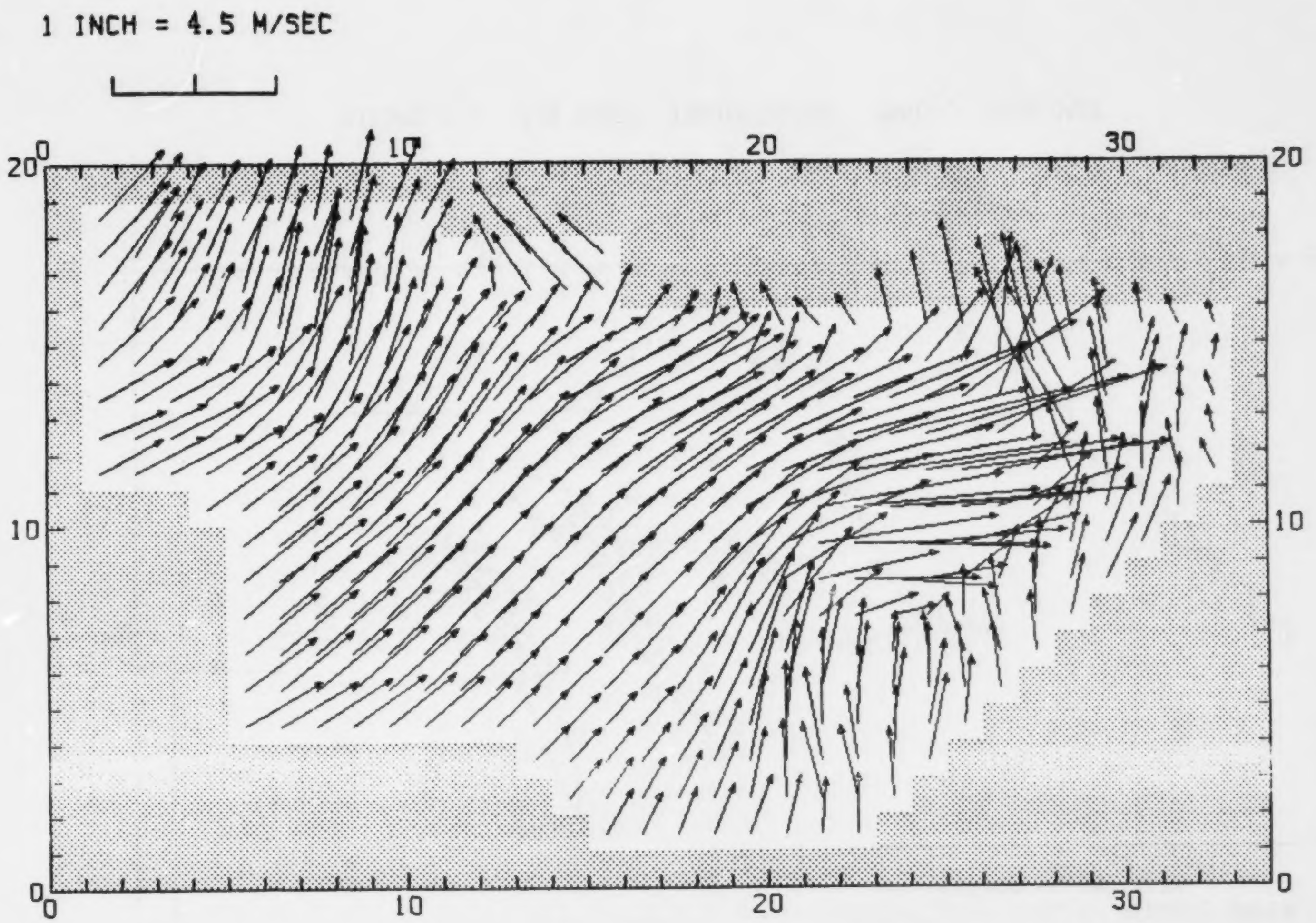
(f) Sensitivity Case 1 Between the Hours of 11 and 12 LST

FIGURE A-2 (Continued)



(g) Base Case Between the Hours of 18 and 19 LST

FIGURE A-2 (Continued)



(h) Sensitivity Case 1 Between the Hours of 18 and 19 LST

FIGURE A-2 (Concluded)

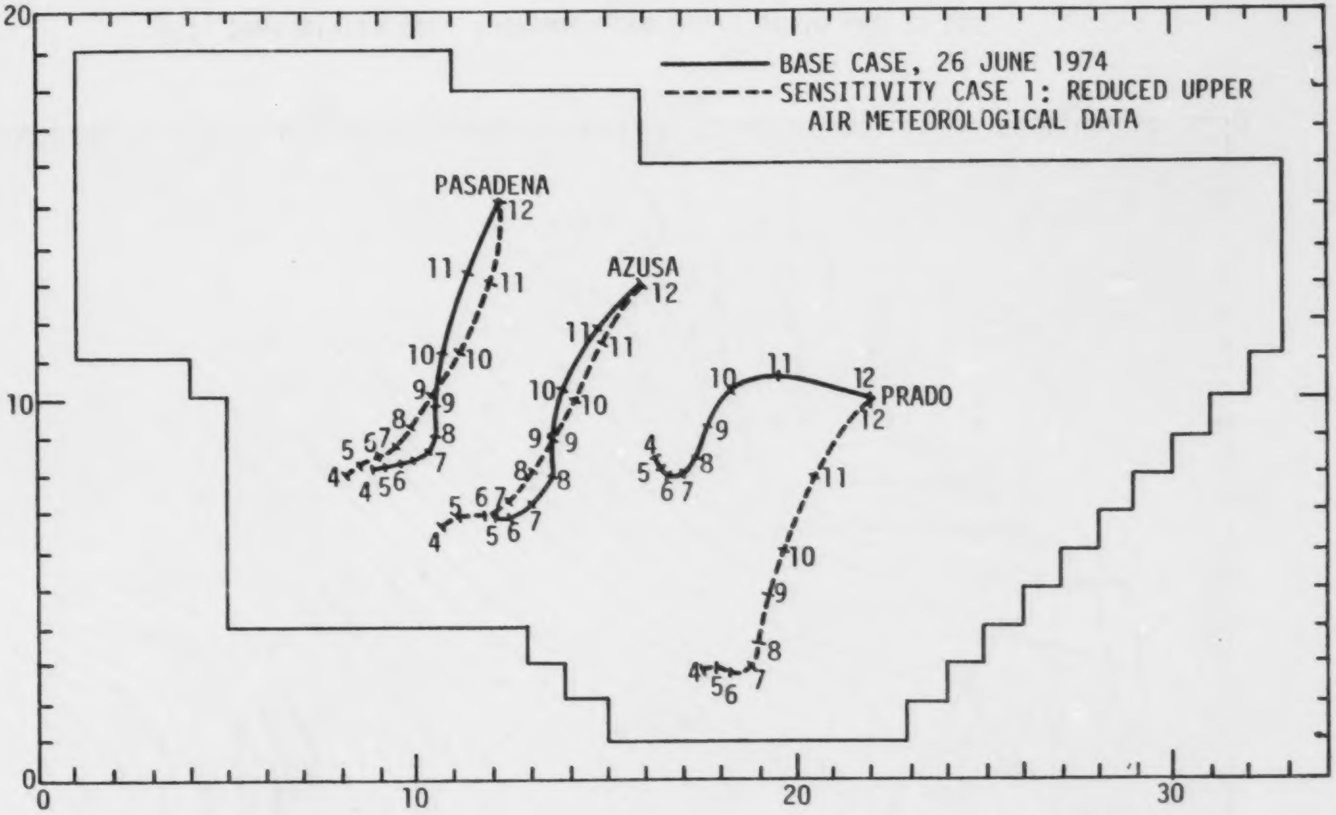


FIGURE A-3. AIR PARCEL TRAJECTORIES: CASE 1--BASE CASE and olefins for the air parcels reaching Azusa and Pasadena are as follows, between the hours of 4 and 5 L.S.T.:

		Sensitivity Case	Base Case
Azusa Air Parcel	Grid	[11-8]	[13-8]
	NO	35 ppb	15 ppb
	NO_2	44 ppb	43 ppb
	Olefins	10 ppb	7 ppb
Pasadena Air Parcel	Grid	[9.9]	[10-9]
	NO	77 ppb	57 ppb
	NO_2	49 ppb	46 ppb
	Olefins	13 ppb	11 ppb
Prado Air Parcel	Grid	[18-3]	[17-9]
	NO	0 ppb	14 ppb
	NO_2	33 ppb	57 ppb
	Olefins	6 ppb	9 ppb

Note that the major difference is for NO concentrations. Higher nitric oxide concentrations are observed in the sensitivity case for the Azusa and Pasadena parcels, and lower concentrations are observed for the Prado parcel. For the hydrocabron/nitrogen oxides ratio observed in the Los Angles basin, this would lead to lower ozone levels for higher NO concentrations and to higher ozone levels for lower NO concentrations. Since only three air parcels and the initial concentrations (neglecting subsequent emissions) were considered, this example is too limited to explain totally the dynamics of an urban airshed. However, it is in agreement with the lower ozone levels observed in mid-basin and the higher ozone levels observed at Prado. This suggests that the wind field perturbation is an important factor in the deviations observed in the predicted ozone levels.

The eddy diffusivity coefficients have not been considered here. These values are affected by the reduction of meteorological input data since they depend on wind velocities. However, Liu et al. (1976) have shown that the urban airshed model is only mildly sensitive to vertical diffusivity.

In conclusion, it appears that the wind field is the most important model input variable in this sensitivity study. The large perturbations in wind direction seem to account for most variations in predicted ozone levels.

3) Sensitivity of Ozone Levels to Upper Air Meteorological Data

Isopleths of maximum ozone levels with time are shown in figure A-4. Ozone profiles are shown in figure A-5 for both the sensitivity case and the base case at the following stations: Anaheim, Fontana, La Habra, Pasadena, Lynwood, Riverside, San Bernardino, Redlands, and Upland. The ozone peak levels are lower at all of these stations except San Bernardino. Higher ozone levels at San Bernardino and Prado may be explained by the absence in the sensitivity case of back flow in the southeastern basin (See the Prado air parcel trajectory in figure A-3). More pollutants are thus transported from the southwest toward Prado, Fontana and Riverside.

Lower ozone levels in the rest of the basin occur despite the occurrence of lower mixing heights. This appears to result from the important perturbations undergone by the wind field, which leads to variations in the precursor levels between the sensitivity case and the base case.

At Riverside and Upland, the peak occurs 2 or 3 hours earlier in the sensitivity case than in the base case. This results from the faster transport of pollutants in the sensitivity case (note the larger air parcel trajectories for the sensitivity case in figure A-3). Consequently, the peak time should be observed farther downwind in the sensitivity case. This may be observed roughly when comparing the following stations:

		La Habra	Upland	Riverside
Peak time (LST):	Base Case	1300	1500	1600
Peak time (LST):	Sensitivity Case	1100	1300	1400

The peak occurs earlier in the sensitivity case, and there is better agreement between the peak hour at the station upwind in the base case than at the same station in the sensitivity case.

4) Conclusions

In this sensitivity study, the model input variables that have been perturbed are the wind field, the mixing heights and the eddy diffusivities. From the results of the model simulations, it appears that the change in wind field has the largest effect on the predicted ozone

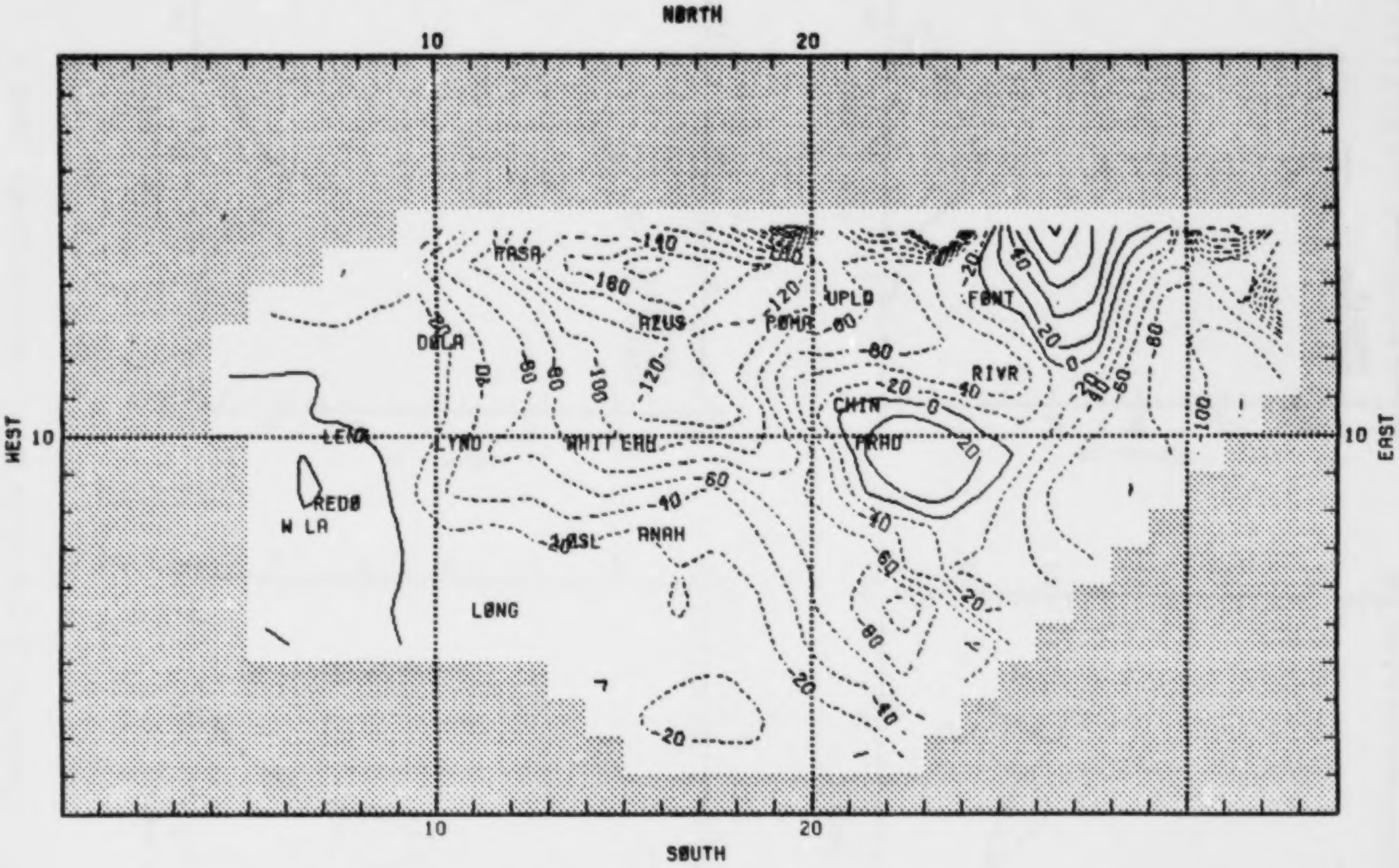

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FIGURE A-4. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb). CASE 1--BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST

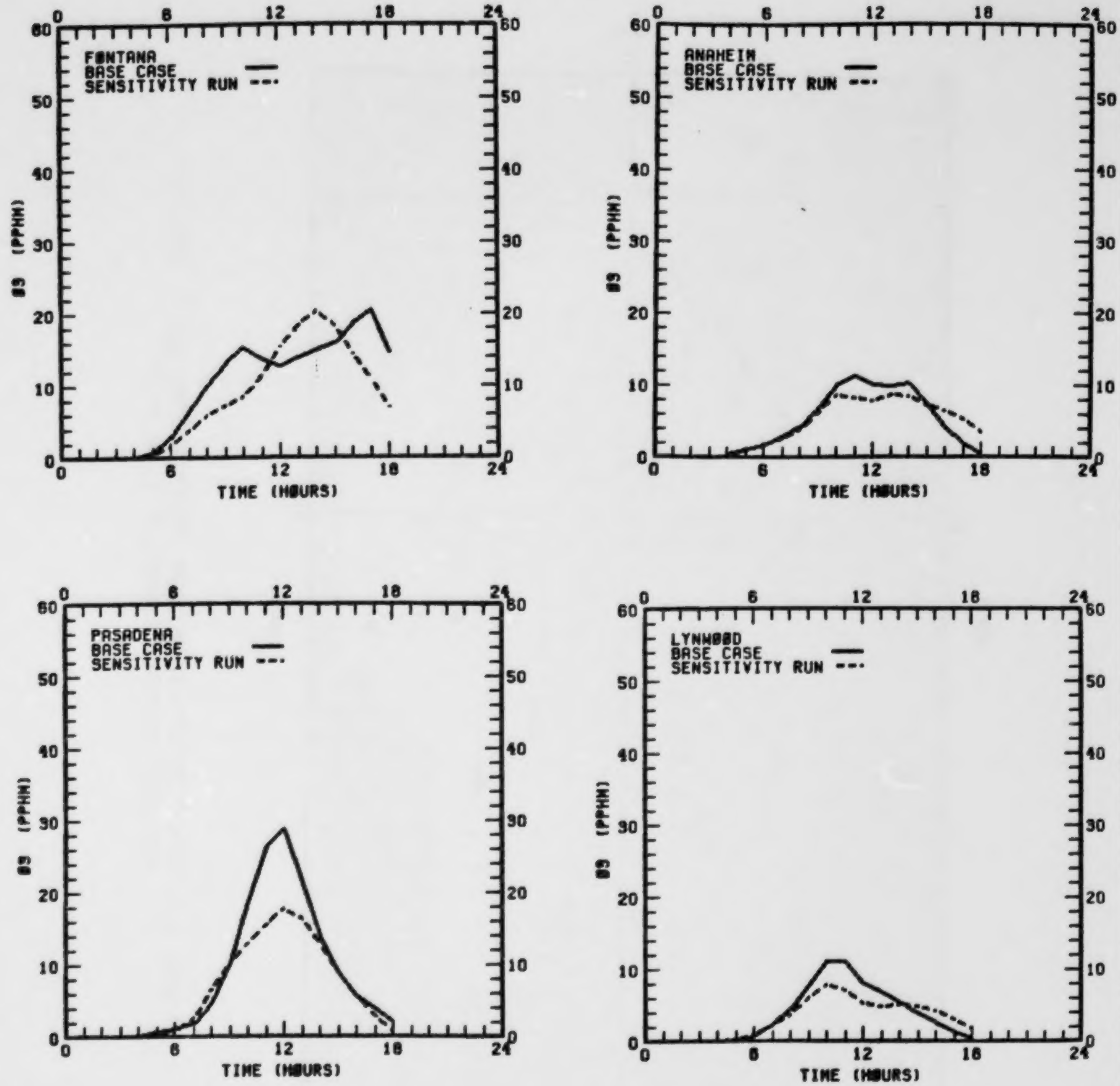


FIGURE A-5. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 1

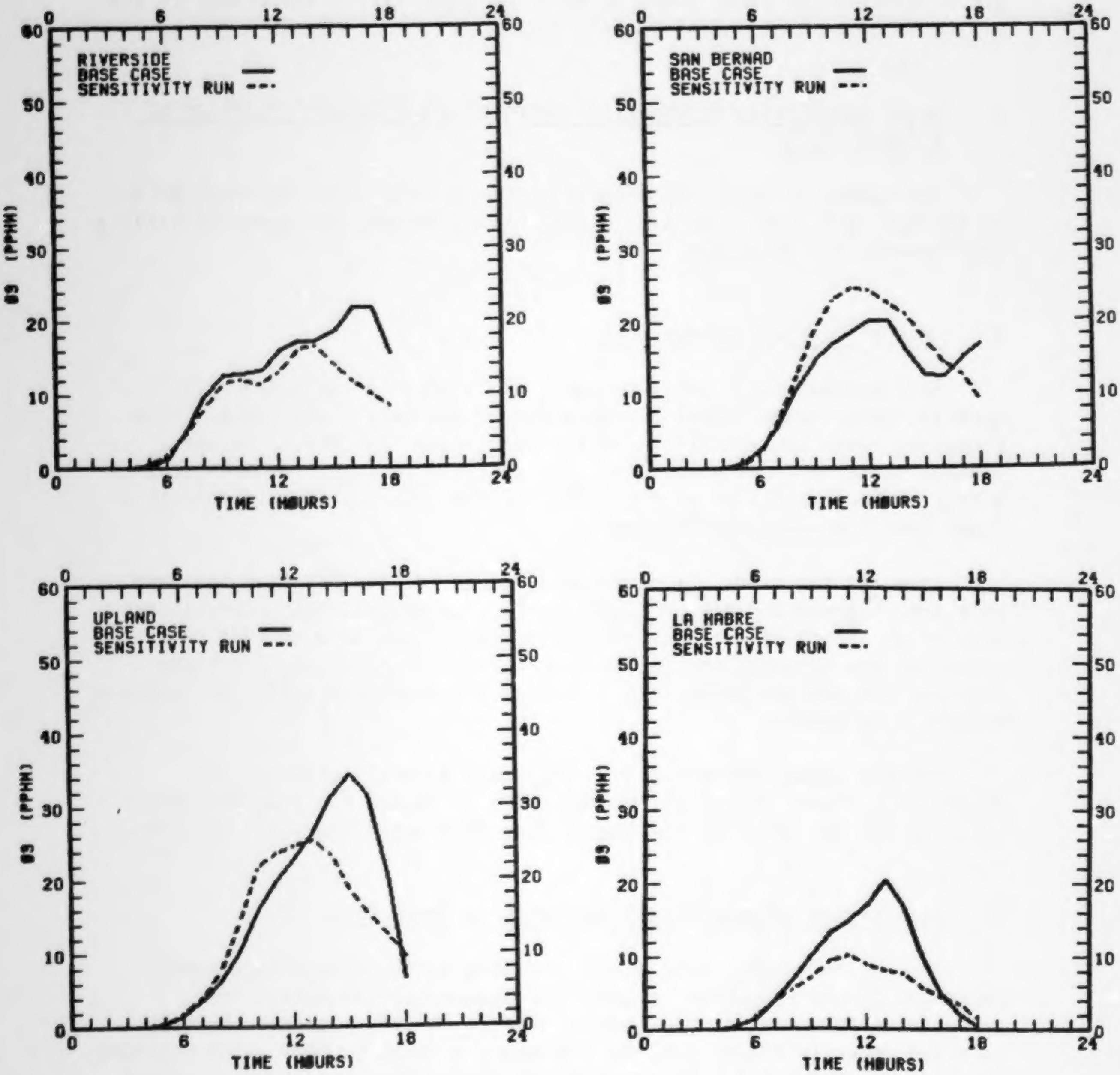


FIGURE A-5 (Concluded)

levels. Though the mixing heights are affected by the reduction in upper air meteorological data, there is no evident pattern to the effect of the mixing heights on pollutant concentrations.

b. Model Sensitivity to Upper Air Meteorological Data--Simulation of 4 August 1975

The number of upper air meteorological stations has been reduced as in the previous case. The wind field, mixing height, and eddy diffusivity coefficients are affected.

1) General Sensitivity Measures

Some general sensitivity measures are listed in table A-3. In general, lower ozone levels are observed in the sensitivity case. When comparing ozone concentrations at the monitoring stations, a larger maximum ozone level is observed in the sensitivity case. However, the actual maximum occurs in grid [11-16] for the sensitivity case, and it is lower than the base-case maximum.

When all the grids are considered, larger deviations from the base case are observed for higher ozone levels. In general, these deviations are not as important as those that occurred for the 26 June 1974 case. Values of the temporal and spatial correlation coefficients are higher than for the previous case (e.g., spatial correlation = 0.974 for stations with $O_3 > 20$ pphm).

Maximum ozone statistics are comparable with all stations and downwind stations. Finally, the reduction in dosage rsulting from the perturbation is less than for the 26 June 1974 meteorological conditions.

2) Sensitivity of Model Input Variables to Input Data

The mixing height, wind field, and eddy diffusivities have been perturbed by the reduction in upper air meteorological data. The differences in mixing depths between the sensitivity case and the base case are shown in figure A-6, for the hours of 0400 to 0500, 1100 to 1200, and 1800 to 1900 L.S.T. In the morning, mixing depths are lower in most of the basin except for higher depths around Riverside and Fontana. Higher mixing depths are observed for the sensitivity case over an increasing part of the basin, and at 1100 most of the basin presents higher depths in the sensitivity case. This pattern persists until 1700 L.S.T., when lower mixing heights are observed in the eastern and western

TABLE A-3. GENERAL SENSITIVITY MEASURES--CASE 2

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	$O_3 > 12$ pphm	$O_3 > 20$ pphm	$O_3 > 12$ pphm	$O_3 > 20$ pphm
Signed deviation	-0.094	-0.034	-0.046	-0.108
Absolute deviation	0.164	0.082	0.168	0.171
Temporal correlation	0.912	0.768	0.878	0.321
Spatial correlation	0.638	0.974	0.396	0.439

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	01.038	00.839
Peak level (pphm):		
Sensitivity case	27.3	31.1
Base case	26.3	37.0
Corresponding locations:		
Sensitivity case	Upland	11 - 16
Base case	Pomona	30 - 16

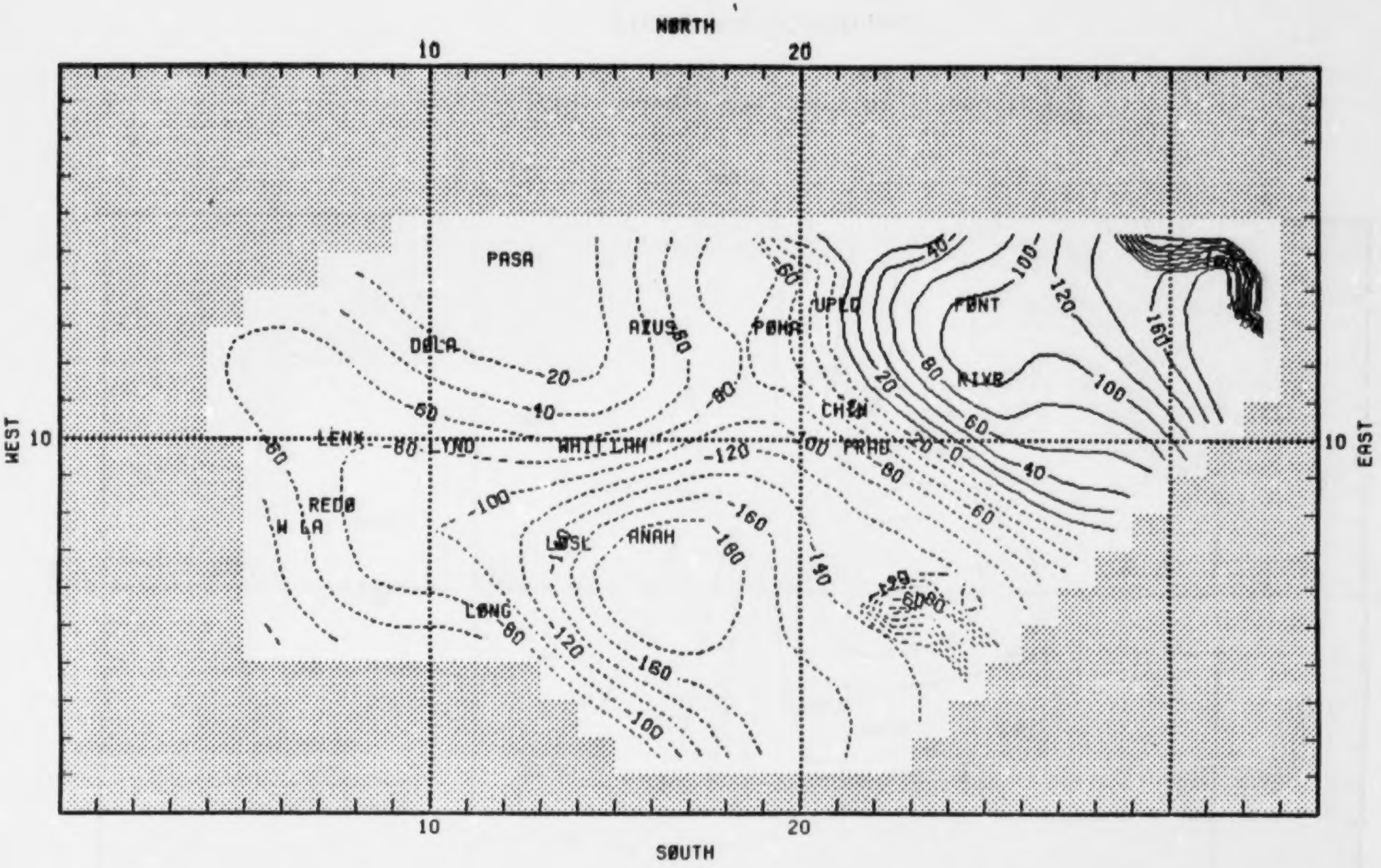
TABLE A-3 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.128	0.132
Peak time lag (hrs)	0.56	0.5

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
-0.017	8,600	8,750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LAH
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ANAH
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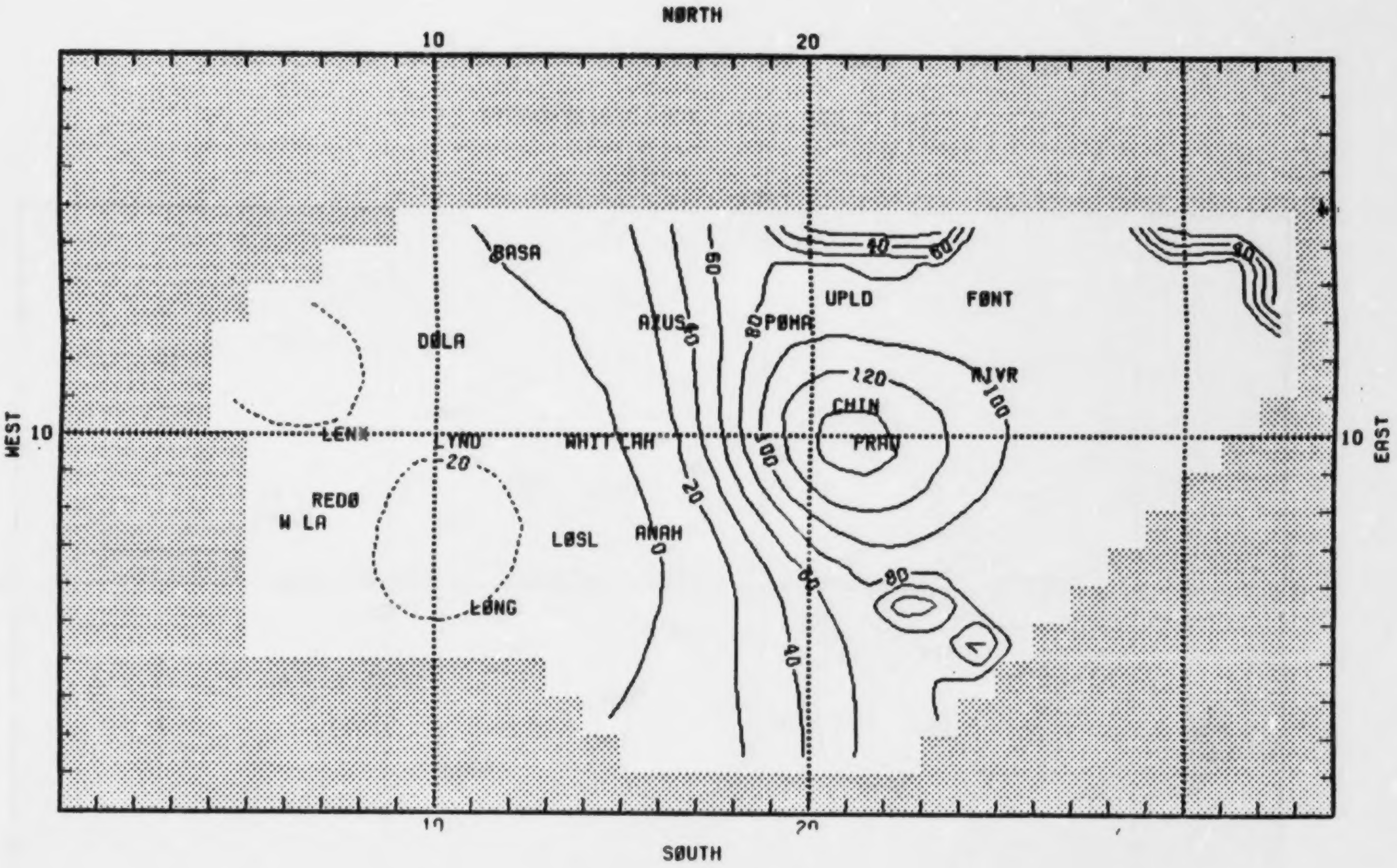
(a) Between the Hours of 4 and 5 LST

FIGURE A-6. MIXING HEIGHT DIFFERENCE (m): CASE 2--BASE CASE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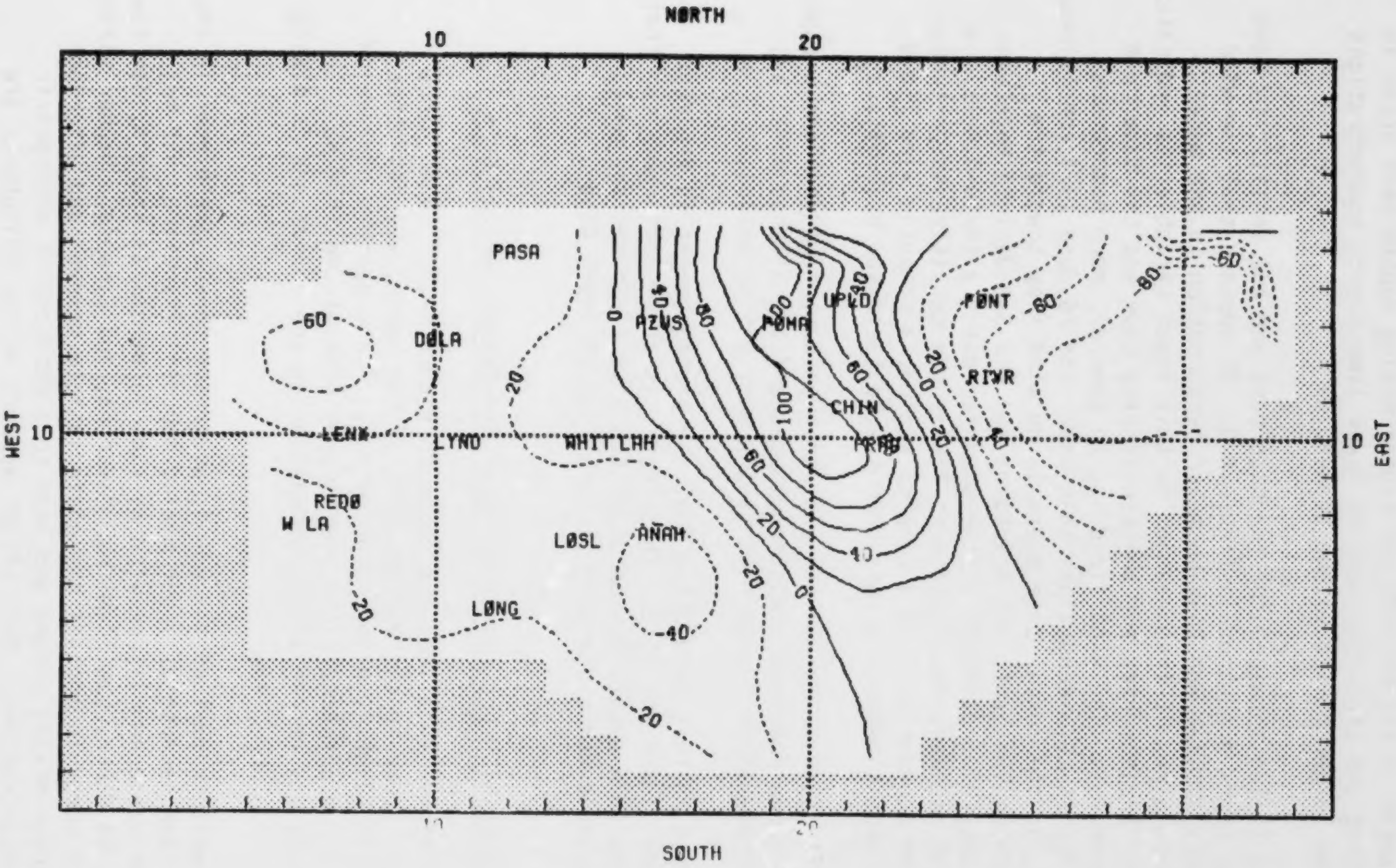
(b) Between the Hours of 11 and 12 EST

FIGURE A-6 (Continued)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UPLD
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PRAD
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60
80
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-40
-60
-80
-60

(c) Between the Hours of 18 and 19 LST

FIGURE A-6 (Concluded)

parts of the basin. Lower mixing heights in the morning hours lead to higher precursor levels, as shown by the NO concentration profiles at Long Beach and Anaheim in figure A-7; the higher mixing depths that occur in the late morning and afternoon tend to lower atmospheric concentrations because of the larger mixing volume available.

The wind fields obtained for the base case and the sensitivity case for different hours are shown in figure A-8. It appears that the wind fields are very similar and that no major perturbation in the model prediction should result from changes in this input variable, as indicated by the two air trajectories for the sensitivity case and the base case shown in figure A-9. The wind field is, in general, more homogeneous under the 4 August 1975 conditions than under the 26 June 1974 conditions; for instance, in the former case there is no wind flow toward the southeast between the Santa Ana Mountains and the San Jacinto Mountains. Because the governing equators of the wind represent a three-dimensional boundary value problem, resultant wind fields are sensitive to perturbations near the boundaries. In a complex region, a computed wind field will be more sensitive than a homogeneous wind field to input data.

Eddy diffusivities should not undergo important perturbations because the wind field has remained almost unchanged and the airshed model has been shown to be rather insensitive to the eddy diffusivities.

It appears in this simulation that the mixing height is the most perturbed model input variable. This result is quite different from that of the 26 June 1974 simulation in which the wind field was the most perturbed variable under the same perturbation of input data.

3) Sensitivity of Ozone Levels to Upper Air Meteorological Data

Maximum ozone deviations are shown in figure A-10. Lower ozone concentrations occur in the eastern part of the basin, whereas other regions present slightly higher ozone levels. This pattern appears in figure A-11 which presents ozone profiles at nine air monitoring stations. This may be explained by considering the variations in mixing depth.

In the western part of the basin, precursor levels are higher in the sensitivity case because of lower mixing depths. Therefore, one may expect higher ozone levels downwind at such locations as Anaheim, downtown Los Angeles, La Habra, Los Alamitos, Pasadena, and Lynwood. Higher mixing depths, which occur in most of the basin in late morning and afternoon, provide a larger mixing volume and lead to a decrease of atmospheric pollutant concentrations. This effect appears as the pollutants are

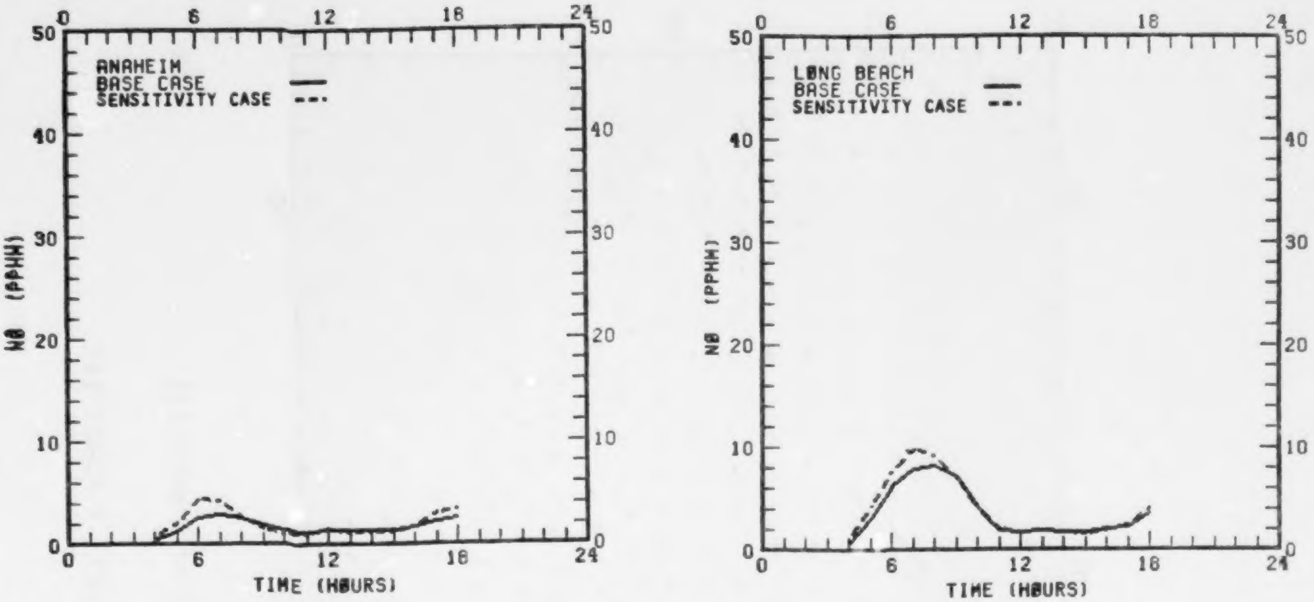
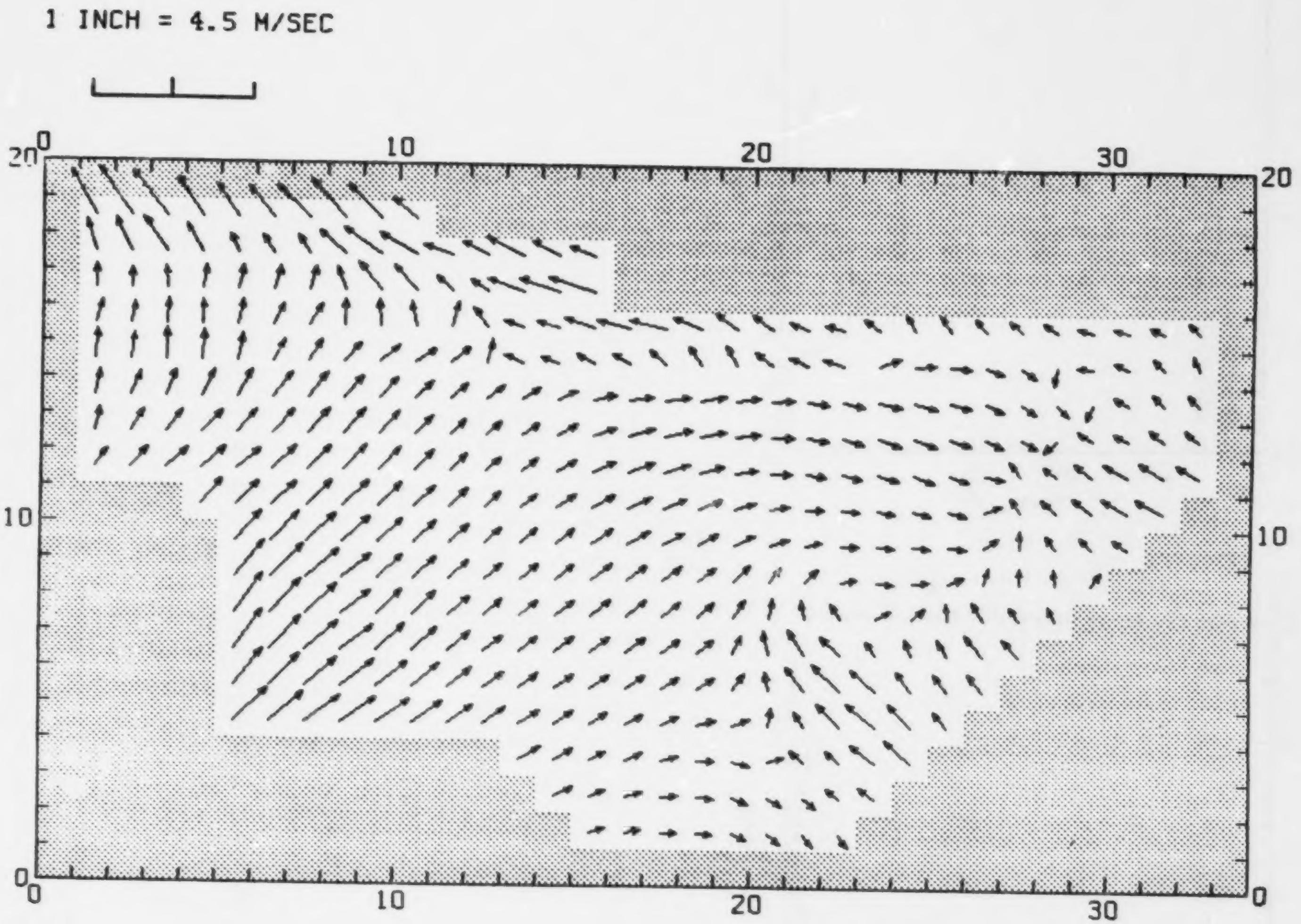
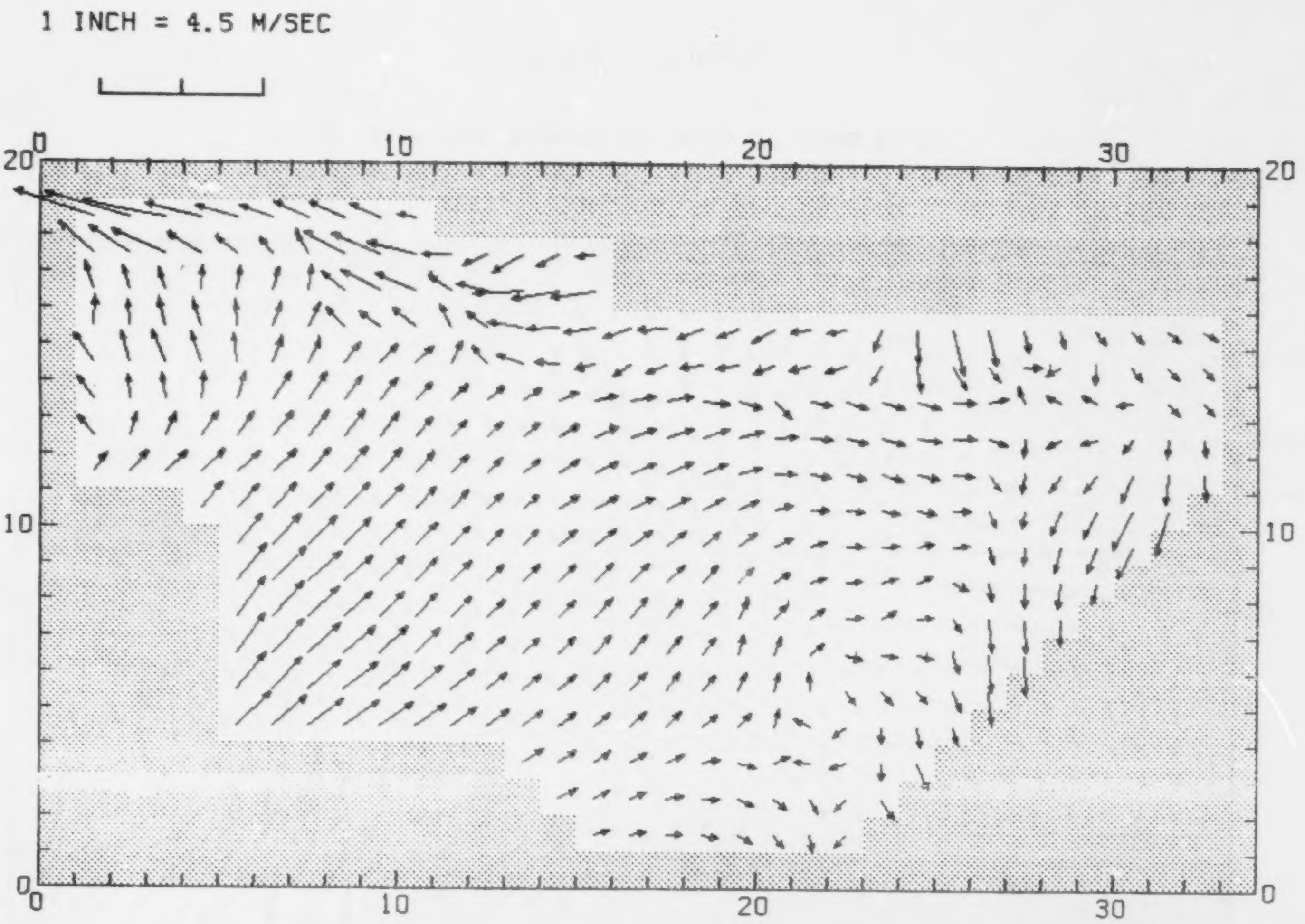


FIGURE A-7. COMPARISON OF PREDICTED NO CONCENTRATIONS: CASE 2



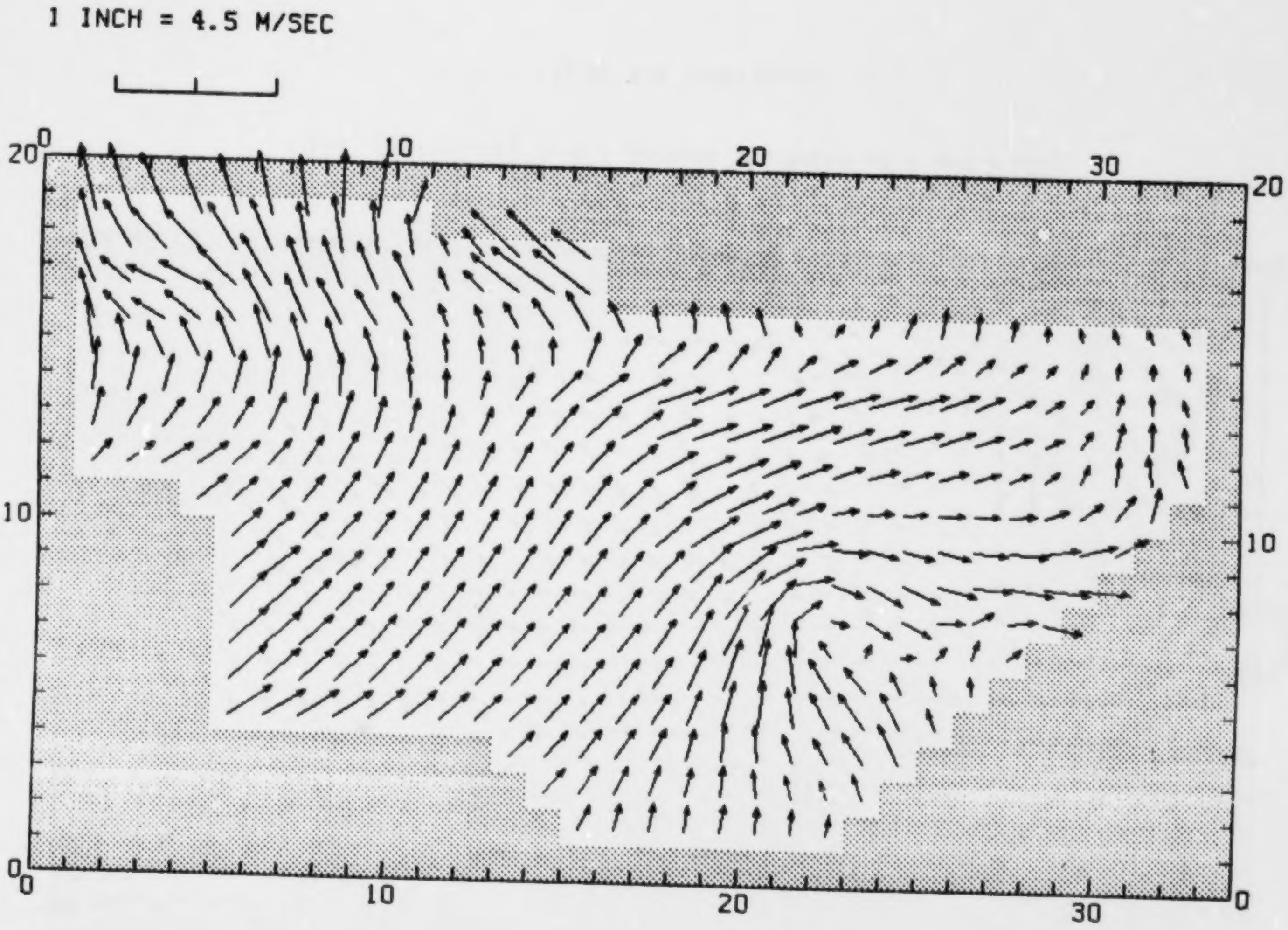
(a) Base Case Between the Hours of 4 and 5 LST

FIGURE A-8. WIND FIELD AT GROUND LEVEL, 4 AUGUST 1975



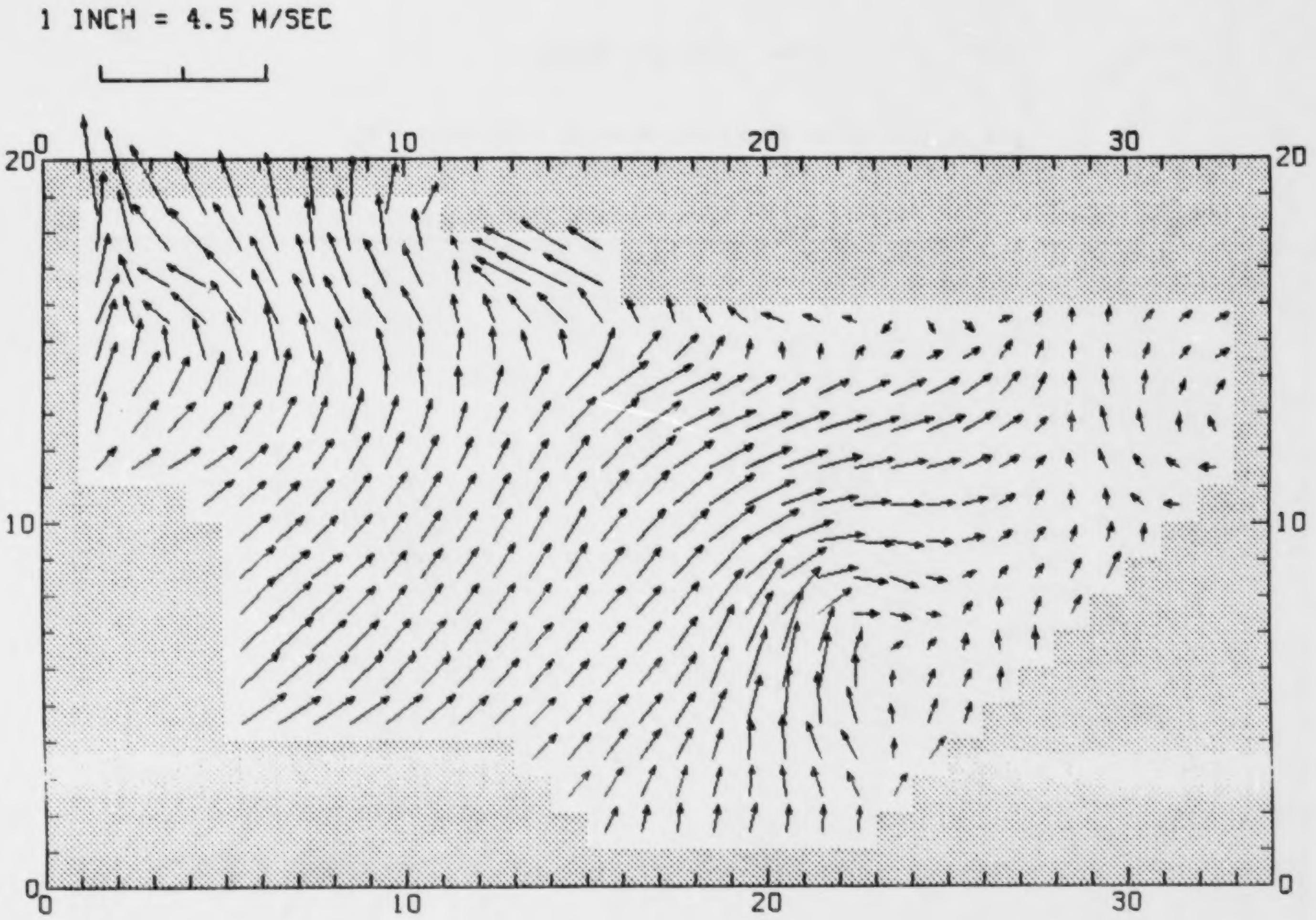
(b) Sensitivity Case 2 Between the Hours of 4 and 5 LST

FIGURE A-8 (Continued)



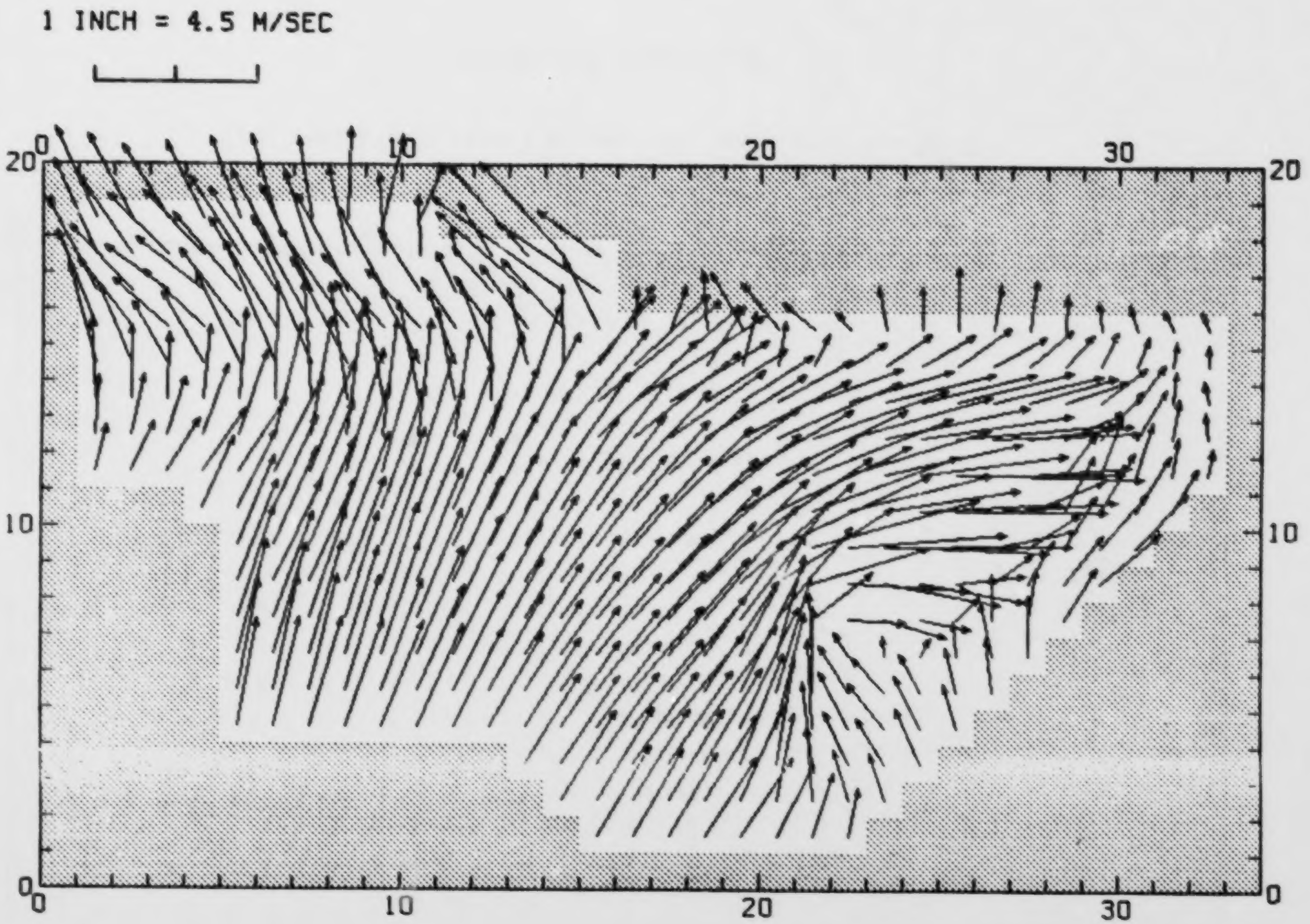
(c) Base Case Between the Hours of 8 and 9 LST

FIGURE A-8 (Continued)



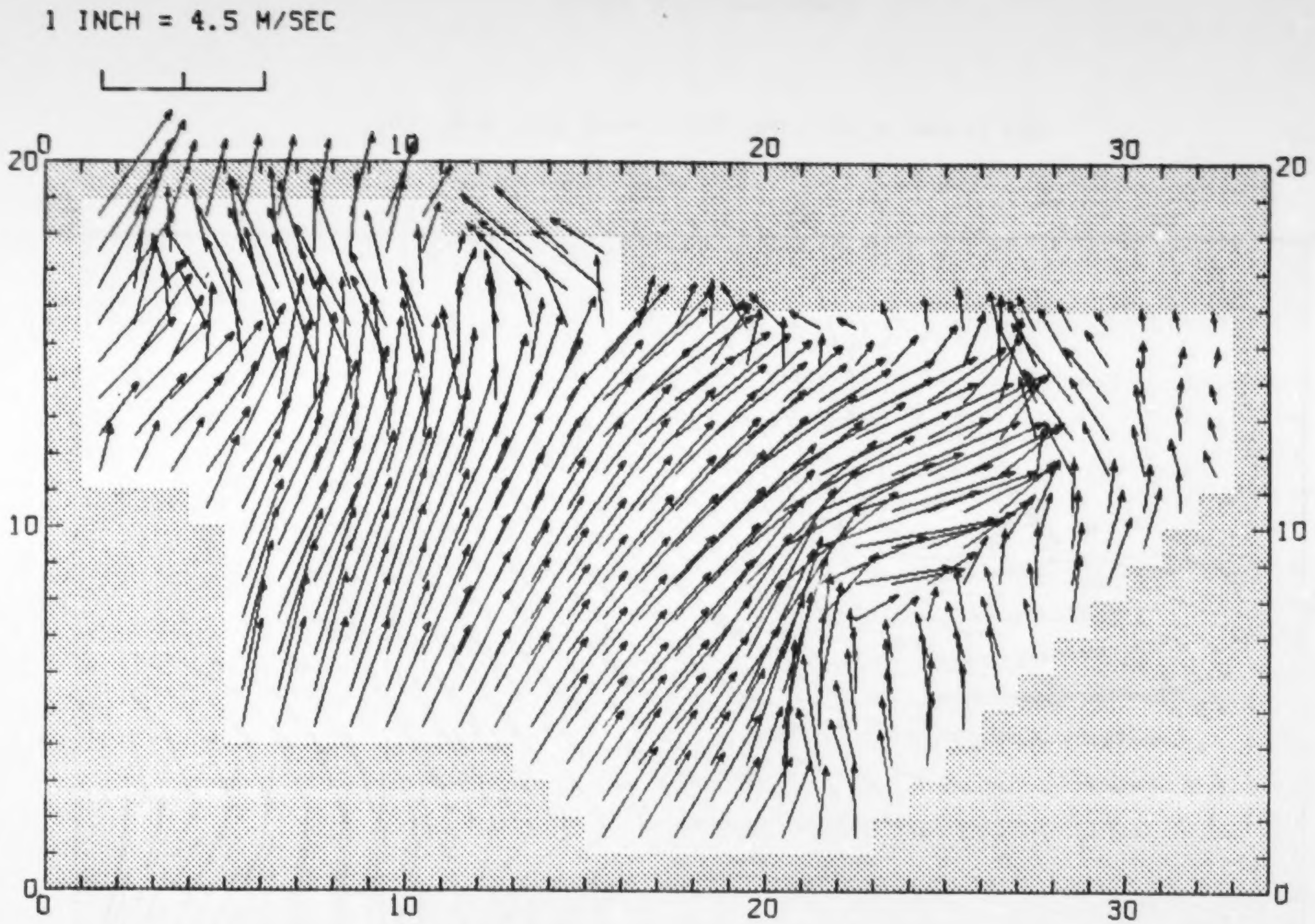
(d) Sensitivity Case 2 Between the Hours of 8 and 9 LST

FIGURE A-8 (Continued)



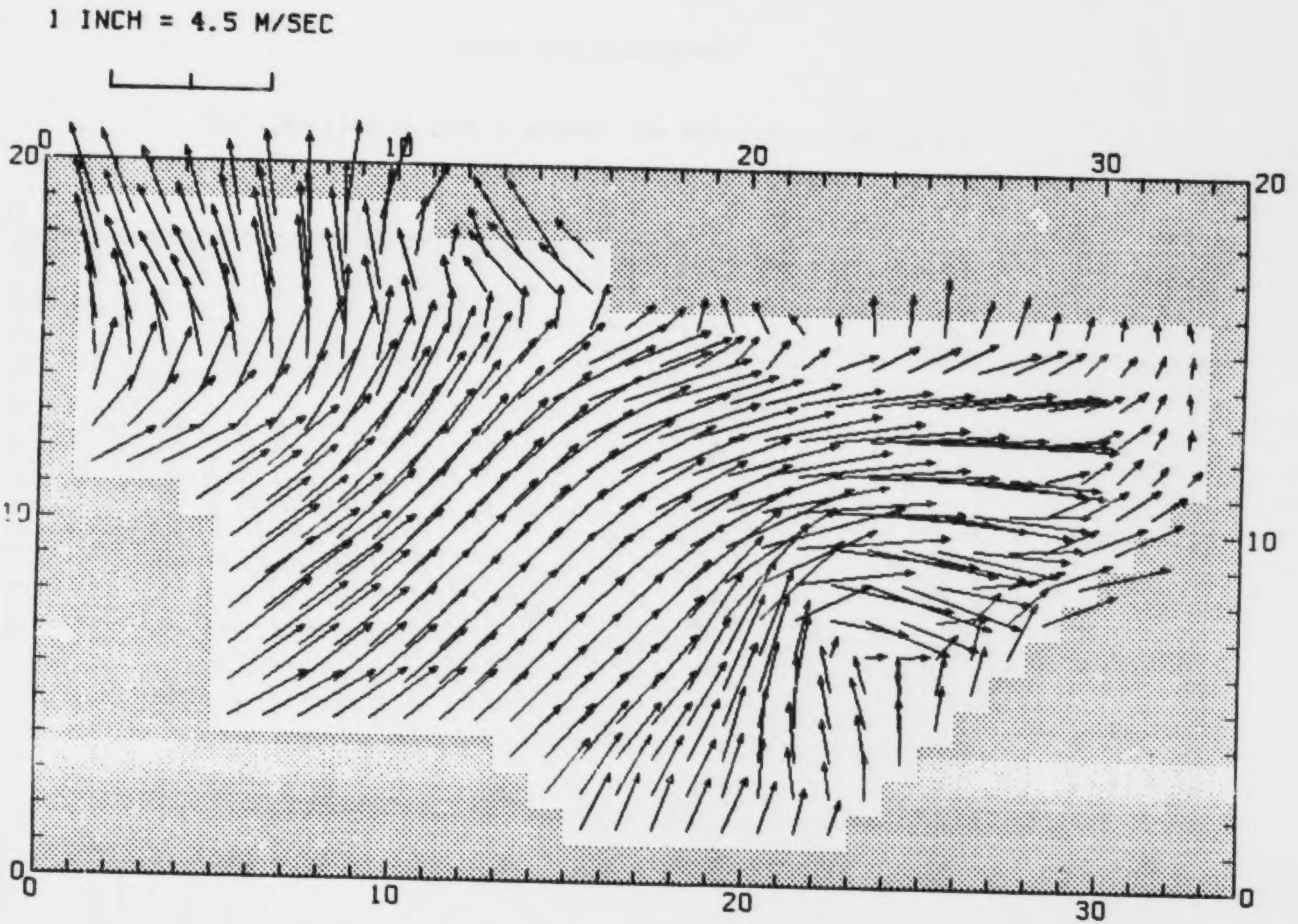
(e) Base Case Between the Hours of 11 and 12 LST

FIGURE A-8 (Continued)



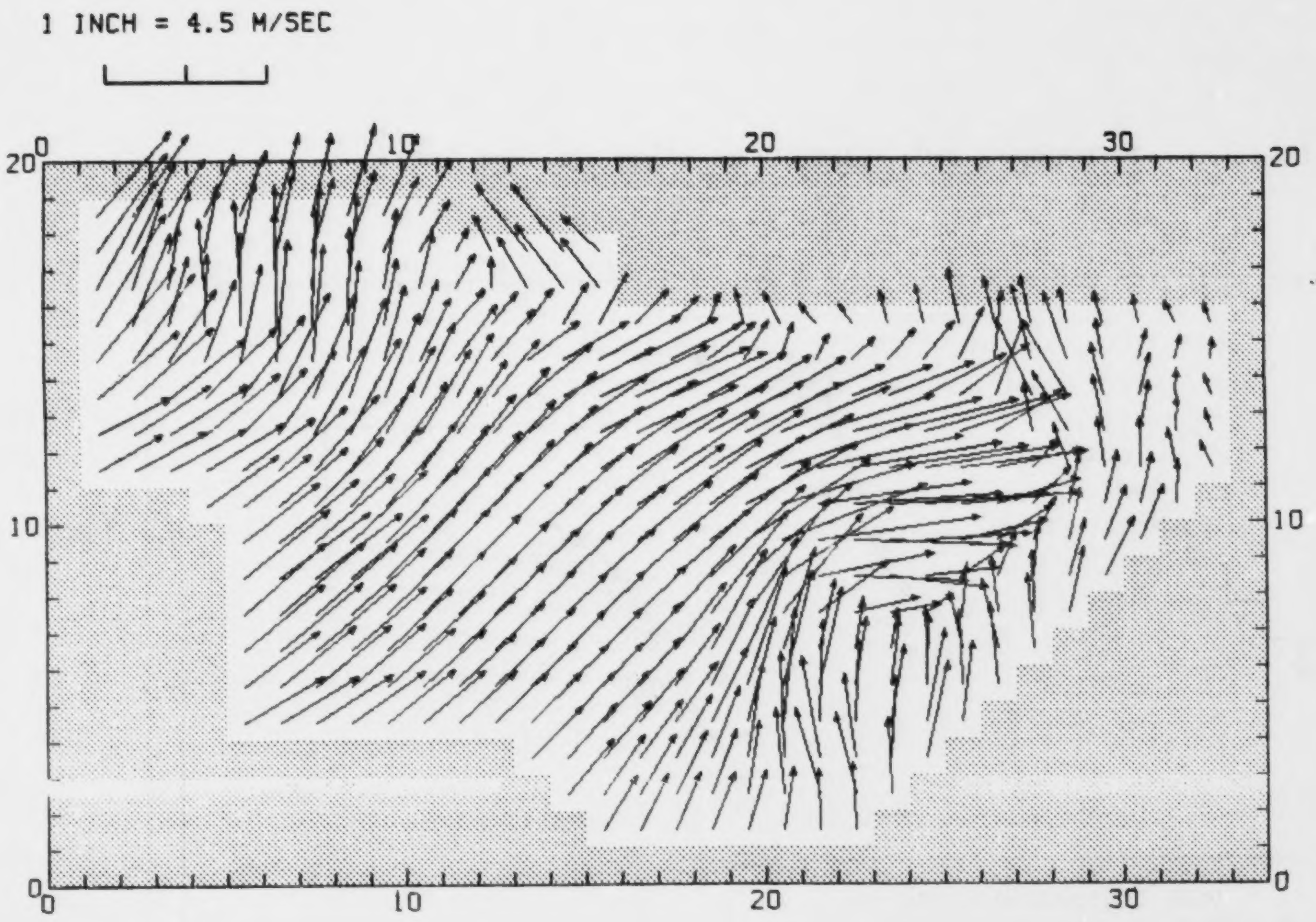
(f) Sensitivity Case 2 Between the Hours of 11 and 12 LST

FIGURE A-8 (Continued)



(g) Base Case Between the Hours of 18 and 19 LST

FIGURE A-8 (Continued)



(h) Sensitivity Case 2 Between the Hours of 18 and 19 LST

FIGURE A-8 (Concluded)

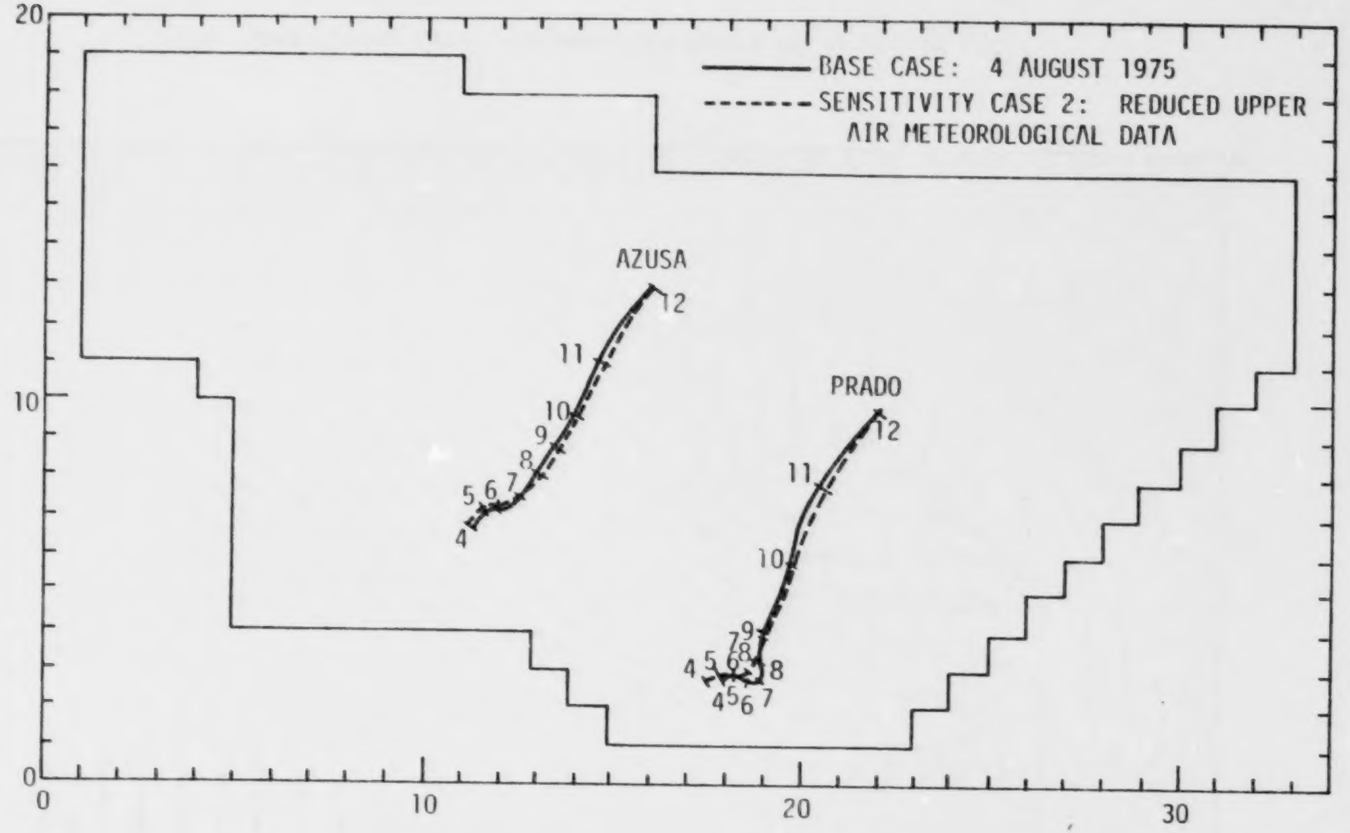


FIGURE A-9. AIR PARCEL TRAJECTORIES: CASE 2--BASE CASE

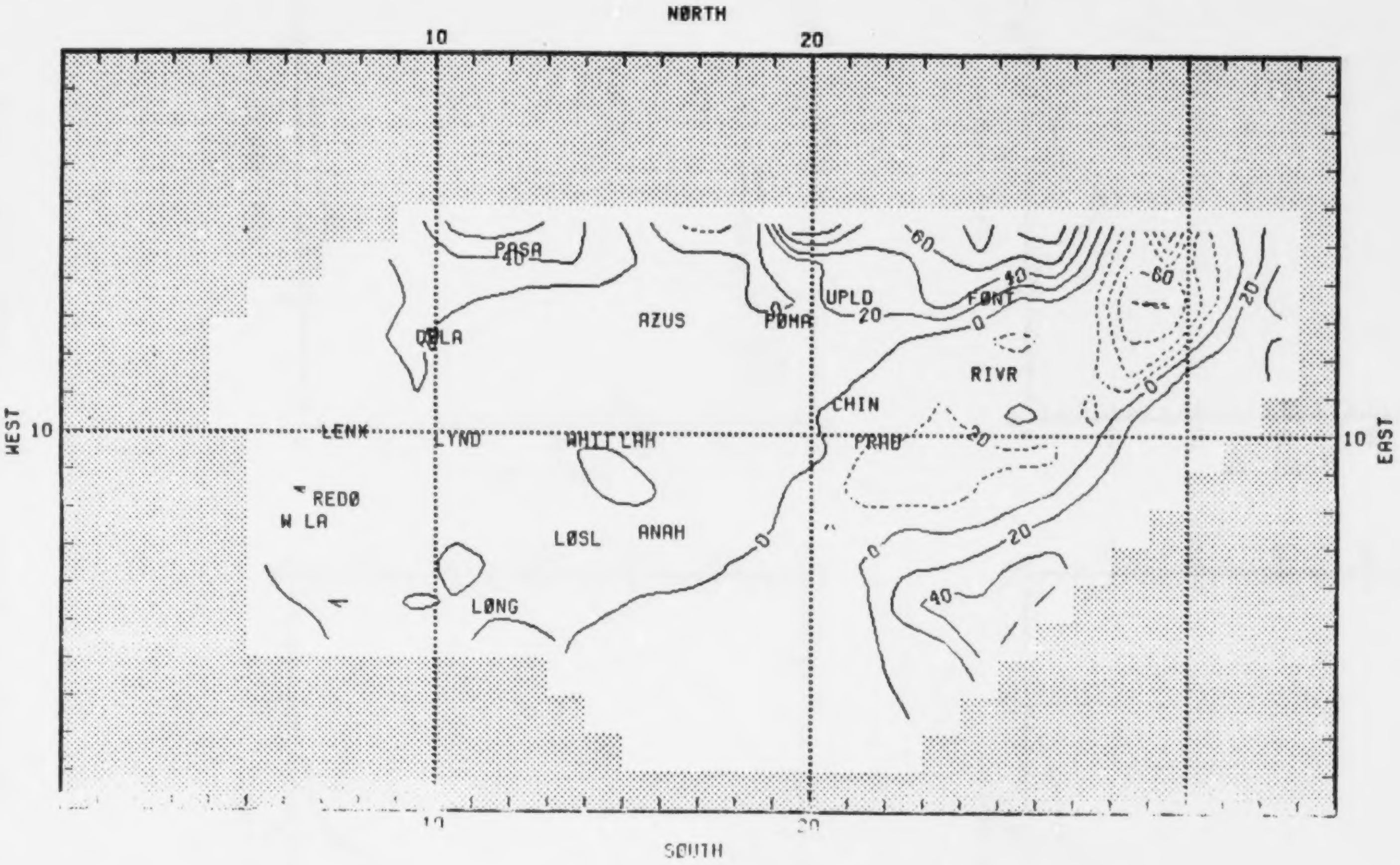

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FIGURE A-10. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 2--BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST

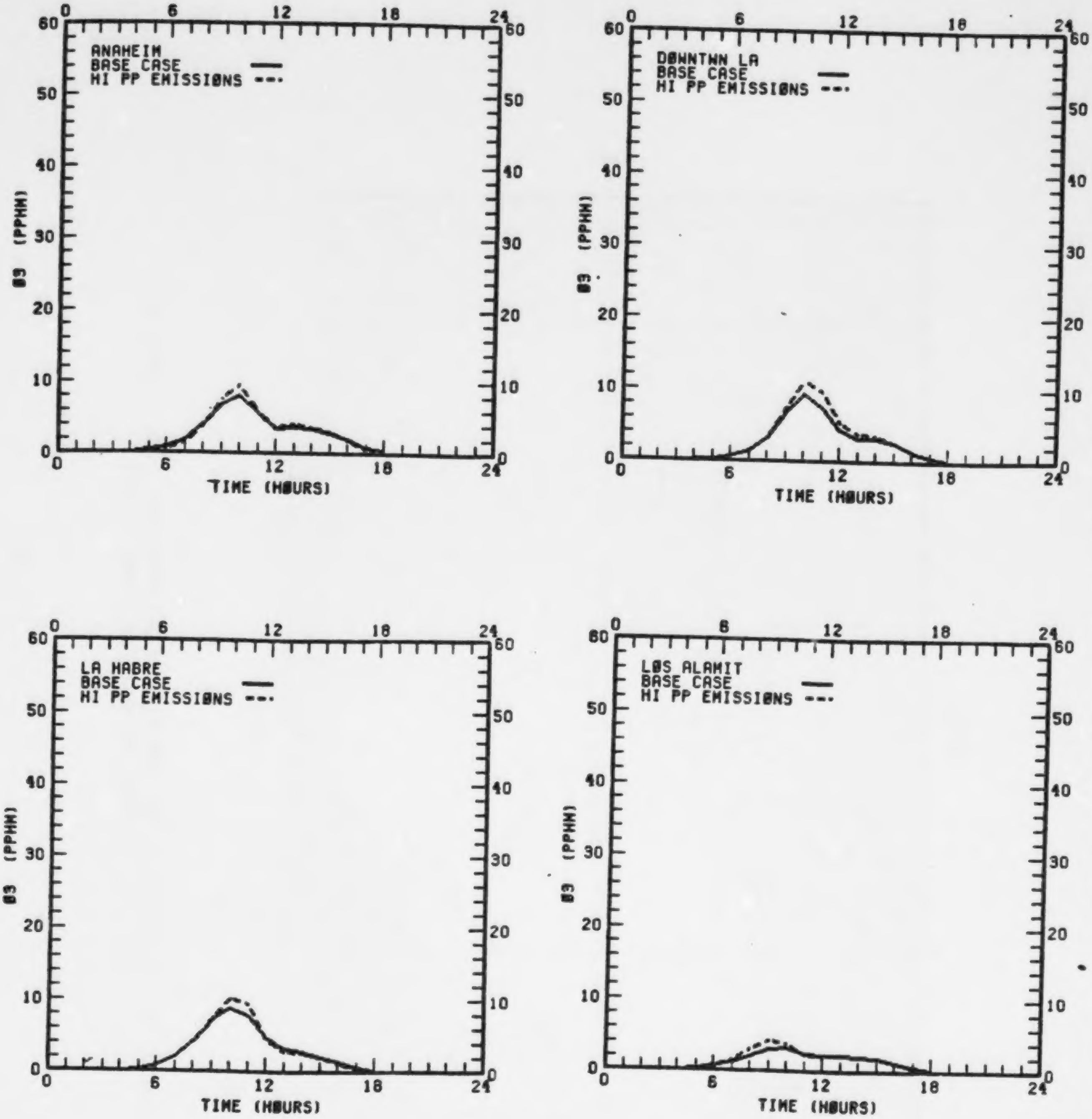


FIGURE A-11. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 2

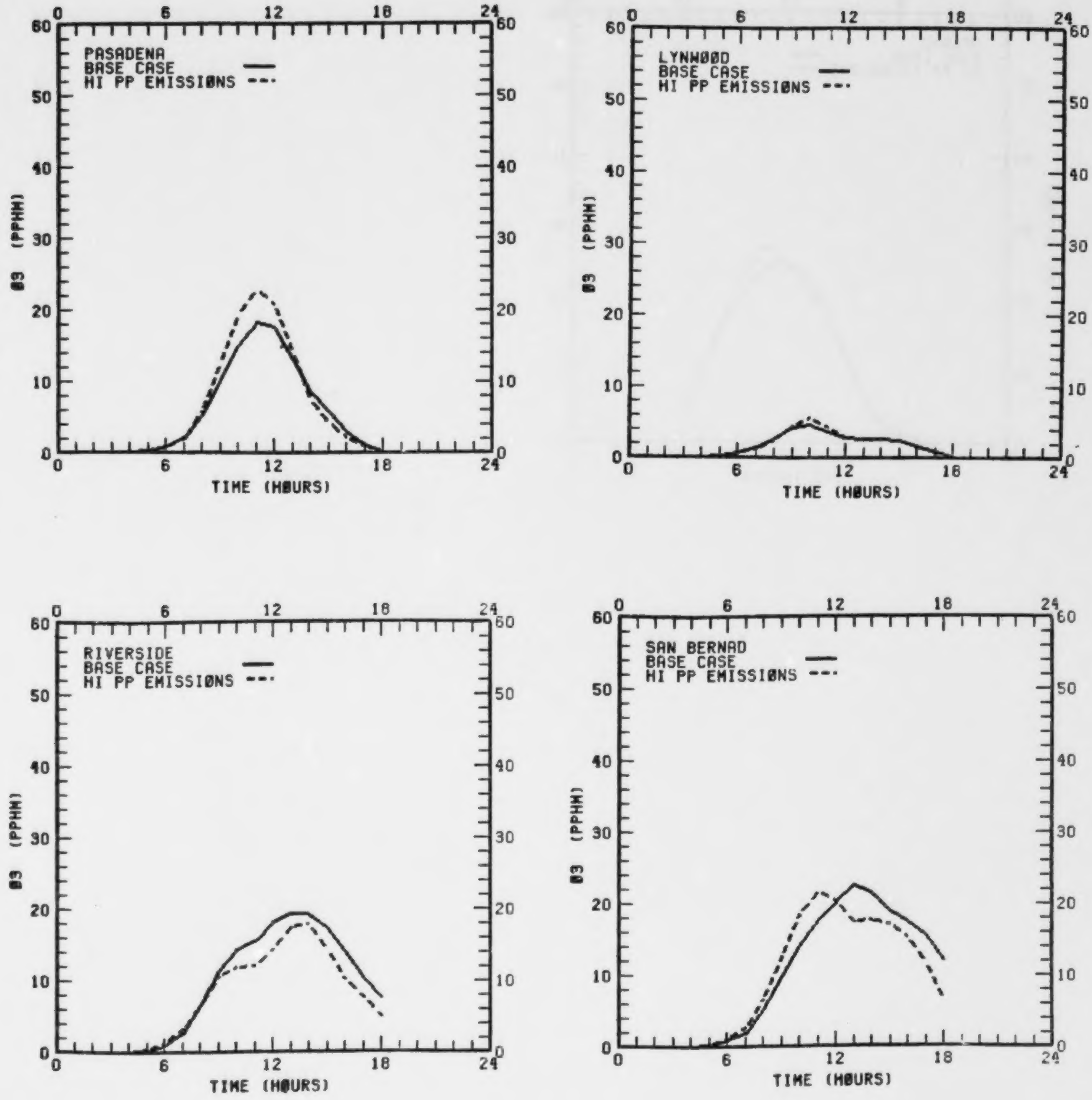


FIGURE A-11 (Continued)

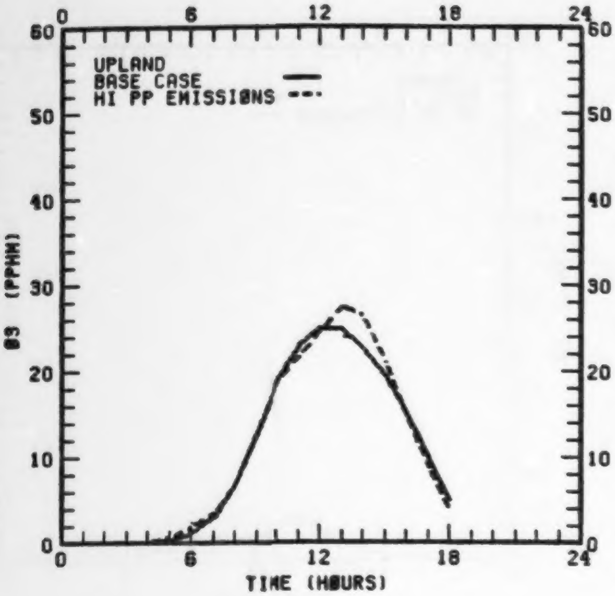


FIGURE A-11 (Concluded)

transported further downwind, e.g., at San Bernardino and Riverside. It is apparent also in the ozone profiles at mid-basin stations, such as Pasadena. The ozone peak is higher because of higher precursor levels, but the increasing mixing volume leads to rapidly decreasing ozone concentrations; at 1400 L.S.T., ozone levels are lower than in the base case.

4) Conclusions

It appears that reduction of upper air meteorological data strongly affects model predictions. With the 26 June 1974 meteorology, wind field variations created the largest changes from the base case, whereas mixing depth variations were most influential with the 4 August 1975 meteorology.

c. Model Sensitivity to Surface Meteorological Data--Simulation of 26 June 1974

The number of upper air meteorological stations has been reduced as in the previous cases. The number of surface meteorological stations has also been reduced. By comparing the results of this simulation with (1) the corresponding base case and (2) the sensitivity case with reduced upper air meteorological data, one can evaluate the impact of reduced surface meteorological data on model predictions.

1) General Sensitivity Measures

Some measures of the general sensitivity of the model are presented in tables A-4 and A-5, for comparisons with the base case and the former sensitivity case (case 1: reduced upper air meteorological data), respectively. Deviations in ozone levels from the June base case are similar to those in case 1. Notice that the overall maximum level in grid cell [30-16] is much higher for this case (53.1 pphm, compared with 31.6 pphm in case 1). The deviations in peak levels from the base case at the air monitoring stations are of the same order as in case 1 (table A-4 and A-5), but there is some discrepancy between this case and case 1 (table A-2). (This is possible since absolute values are considered in this measure.) The peak time lag has increased slightly also.

It appears that the dosage is the most sensitive measure in this study. The percent deviation in dosage between this case and case 1 is 23.9. The effect of surface meteorological data on model predictions is not negligible. This fact would not be apparent if only ozone level

TABLE A-4. GENERAL SENSITIVITY MEASURES--CASE 3 VS. BASE CASE

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	O_3 > 12 pphm	O_3 > 20 pphm	O_3 > 12 pphm	O_3 > 20 pphm
Signed deviation	-0.172	-0.367	-0.225	-0.392
Absolute deviation	0.320	0.389	0.347	0.443
Temporal correlation	-0.183	-0.455	-0.034	-0.293
Spatial correlation	0.310	-0.185	0.247	0.331

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	0.710	1.366
Peak level (pphm):		
Sensitivity case	25.2	53.1
Base case	35.5	38.9
Corresponding locations:		
Sensitivity case	San Bernardino	30 - 16
Base case	Azusa	33 - 14

TABLE A-4 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.249	0.260
Peak time lag (hrs)	2.17	2.37

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
-0.260	7,400	10,000

TABLE A-5. GENERAL SENSITIVITY MEASURES--CASE 3 VS. CASE 1

(a) General Ozone Level Deviations

	Station Statistics		Grid Statistics	
Sensitivity Measure	O_3 > 12 pphm	O_3 > 20 pphm	O_3 > 12 pphm	O_3 > 20 pphm
Signed deviation	-0.018	-0.058	-0.007	-0.050
Absolute deviation	0.259	0.097	0.171	0.167
Temporal correlation	0.947	0.519	0.826	0.521
Spatial correlation	0.810	0.272	0.656	0.632

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ case 1 ratio	0.989	1.690
Peak level (pphm):		
Sensitivity case	25.2	53.1
Case 1	25.5	31.6
Corresponding locations:		
Sensitivity case	San Bernardino	30 - 16
Case 1	Upland	30 - 16

TABLE A-5 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.104	0.108
Peak time lag (hrs)	1.25	1.25

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Case 1 (km^2)
0.239	7,400	5,975

deviations between this sensitivity case and the base case were considered; the comparison with case 1 therefore, is useful to assess the importance of surface meteorological data.

2) Sensitivity of Model Input Variables to Input Data

Meteorological data affect the mixing height, wind field, and eddy diffusivities. The eddy diffusivities are not considered here, since their effect on model predictions is negligible compared to that of the other meteorological variables.

Mixing height differences between this sensitivity case and the base case are shown in figure A-12; the perturbations are similar to those obtained in case 1. The mixing depths are slightly lower in mid basin around 1100 L.S.T. but slightly higher in the afternoon around 1500.

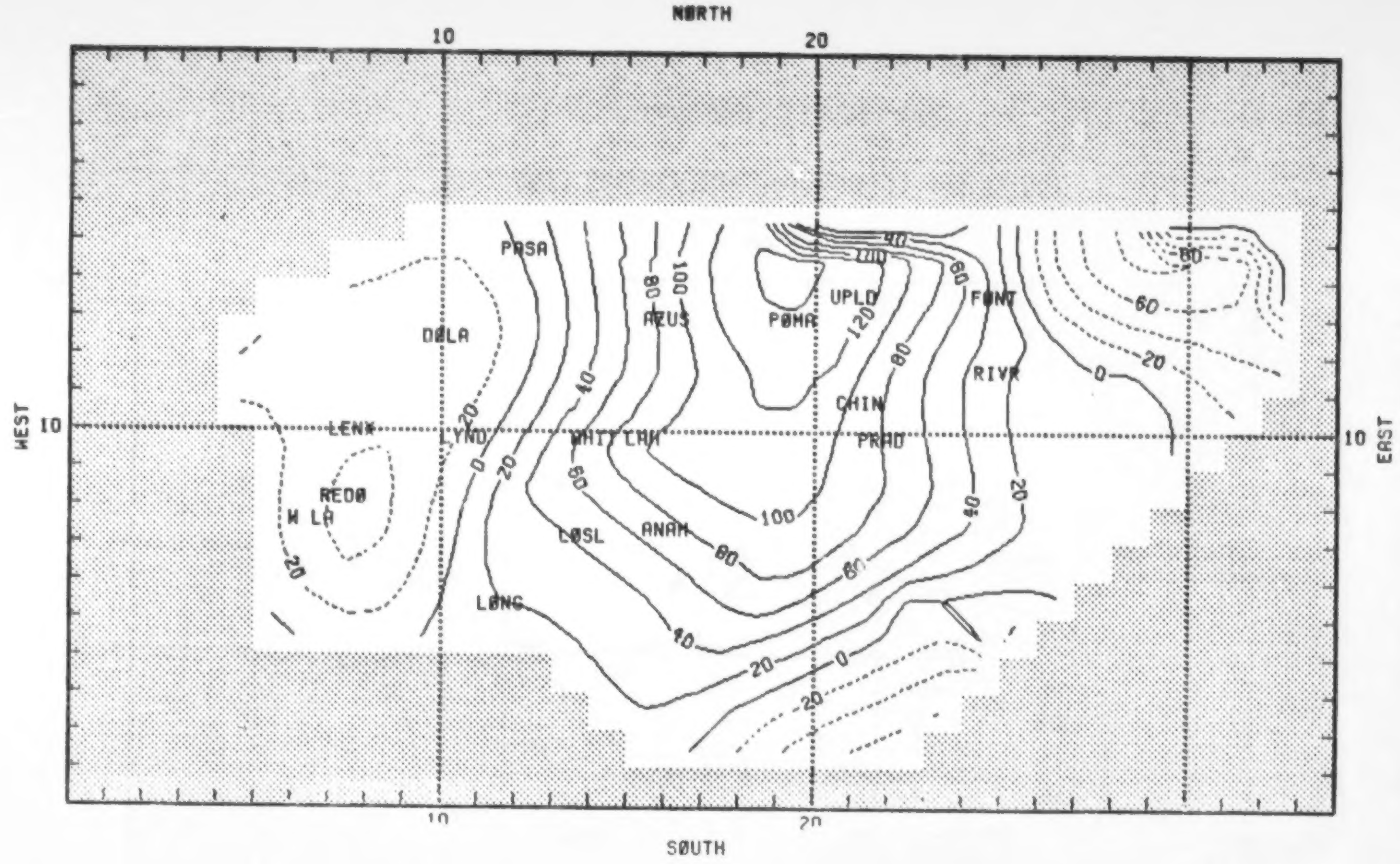
The wind field at ground level, shown in figure A-13 for the hours of 0400 to 0500, 0800 to 0900, 1100 to 1200, and 1800 to 1900 L.S.T., presents a pattern similar to the sensitivity of case 1. The differences, however, are not negligible. Some air parcel trajectories are shown in figure A-14 for this case and case 1. The differences at Azusa and Prado are not as large as those resulting from the reduction in upper air data. In the eastern part of the basin, however, the wind flow is much affected, as shown by the air parcel trajectories that reach Redland at 1200 L.S.T. The strong perturbations on the eastern boundary of the airshed may be a result of the reduction of meteorological boundary values for the wind model.

In mid basin, wind velocities are larger for this sensitivity case than for case 1, as shown in figure A-13. This will result in more atmospheric dispersion and lower the species concentrations (Liu et al., 1976).

It seems that the reduction in surface meteorological data is not as perturbing as the reduction of upper air meteorological data. The mixing depth and wind field are not affected as much as in case 1. However, one should expect some variations in ozone levels as a result of those non-negligible perturbations in the meteorological variables.

3) Sensitivity of Ozone Levels to Surface Meteorological Data

Isopleths of maximum ozone deviations are shown in figures A-15 and A-16 for the comparisons with the base case and case 1, respectively. The largest deviations occur along the eastern boundary of the airshed. It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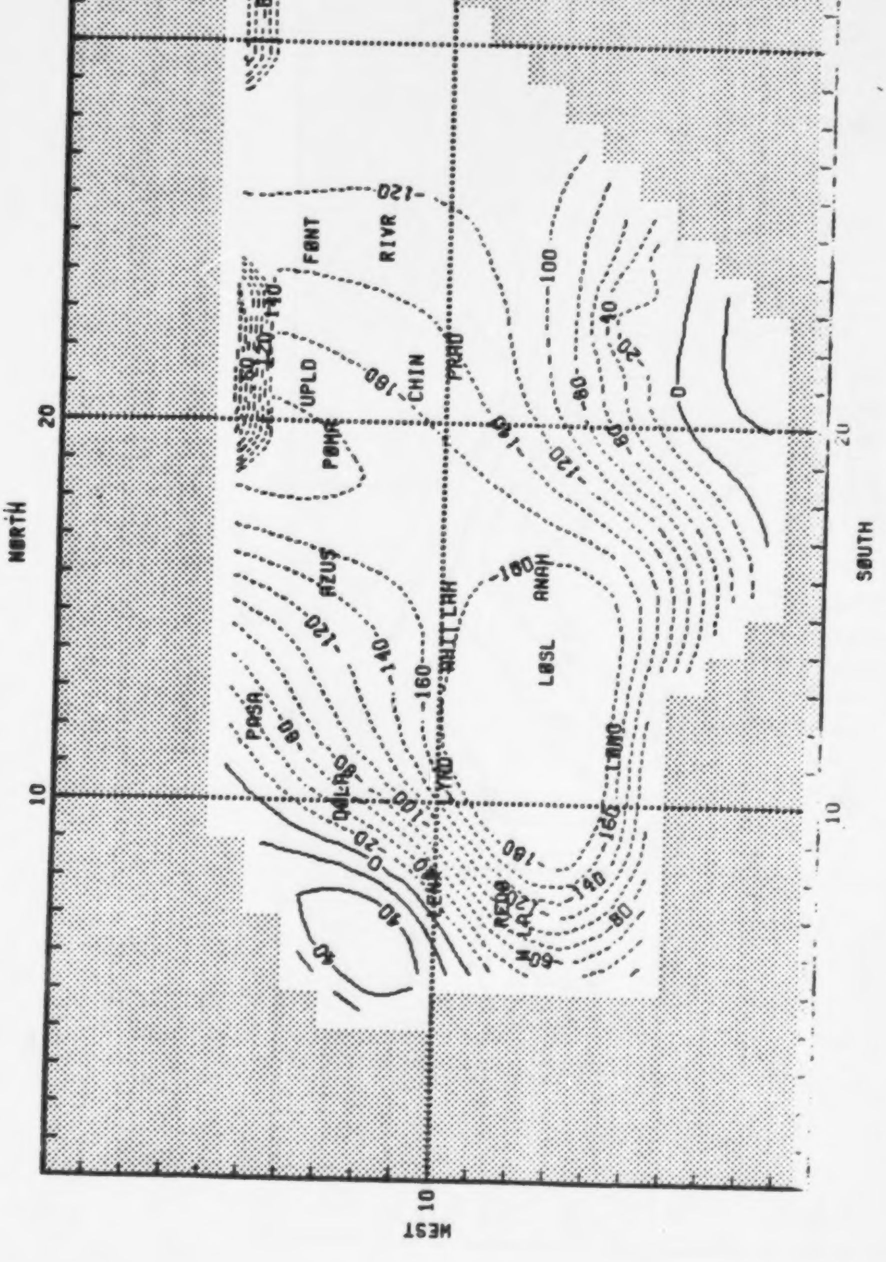
(a) Between the Hours of 4 and 5 LST

FIGURE A-12. MIXING HEIGHT DIFFERENCE (m): CASE 3--BASE CASE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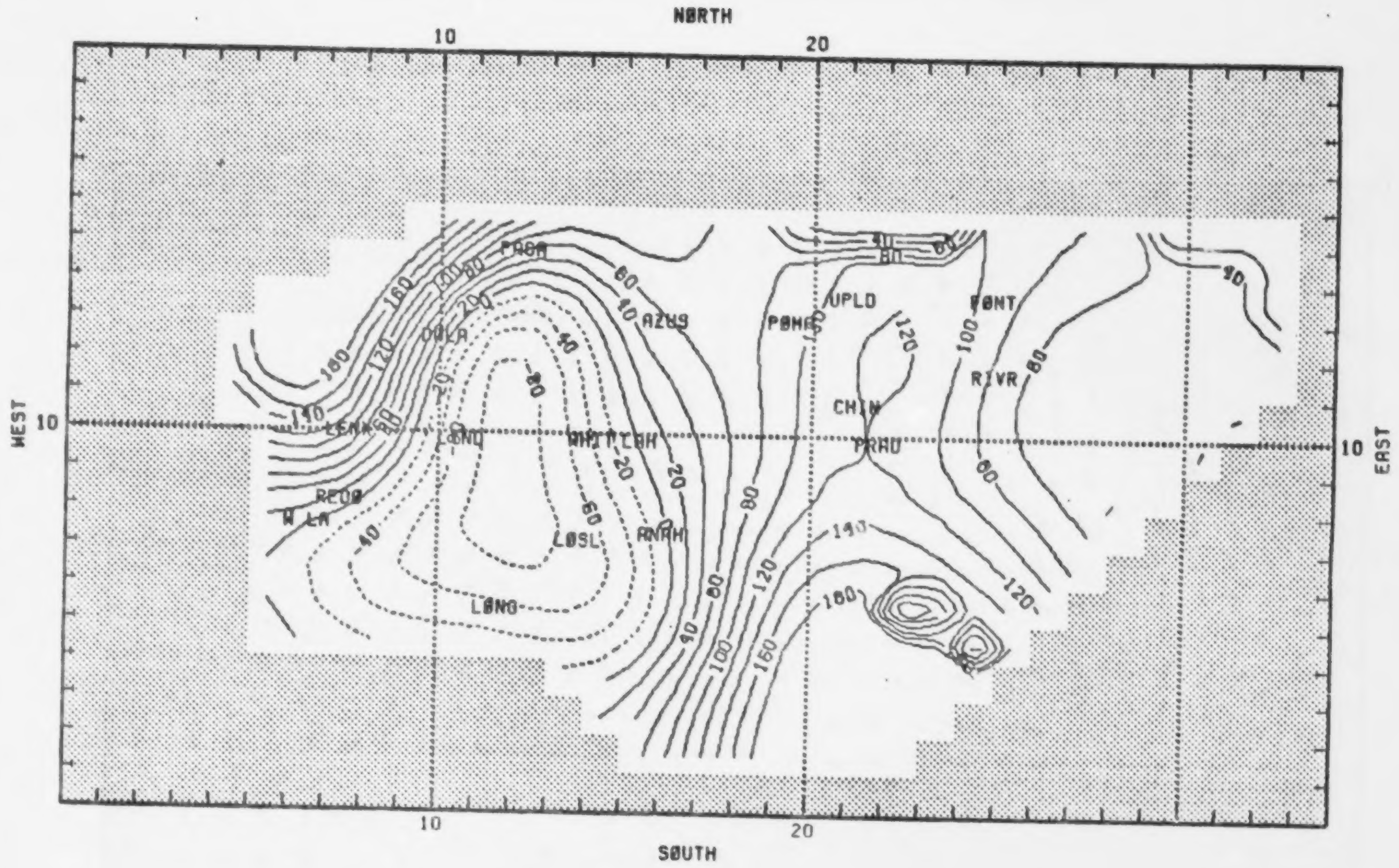
(b) Between the Hours of 11 and 12 LST

FIGURE A-12 (Continued)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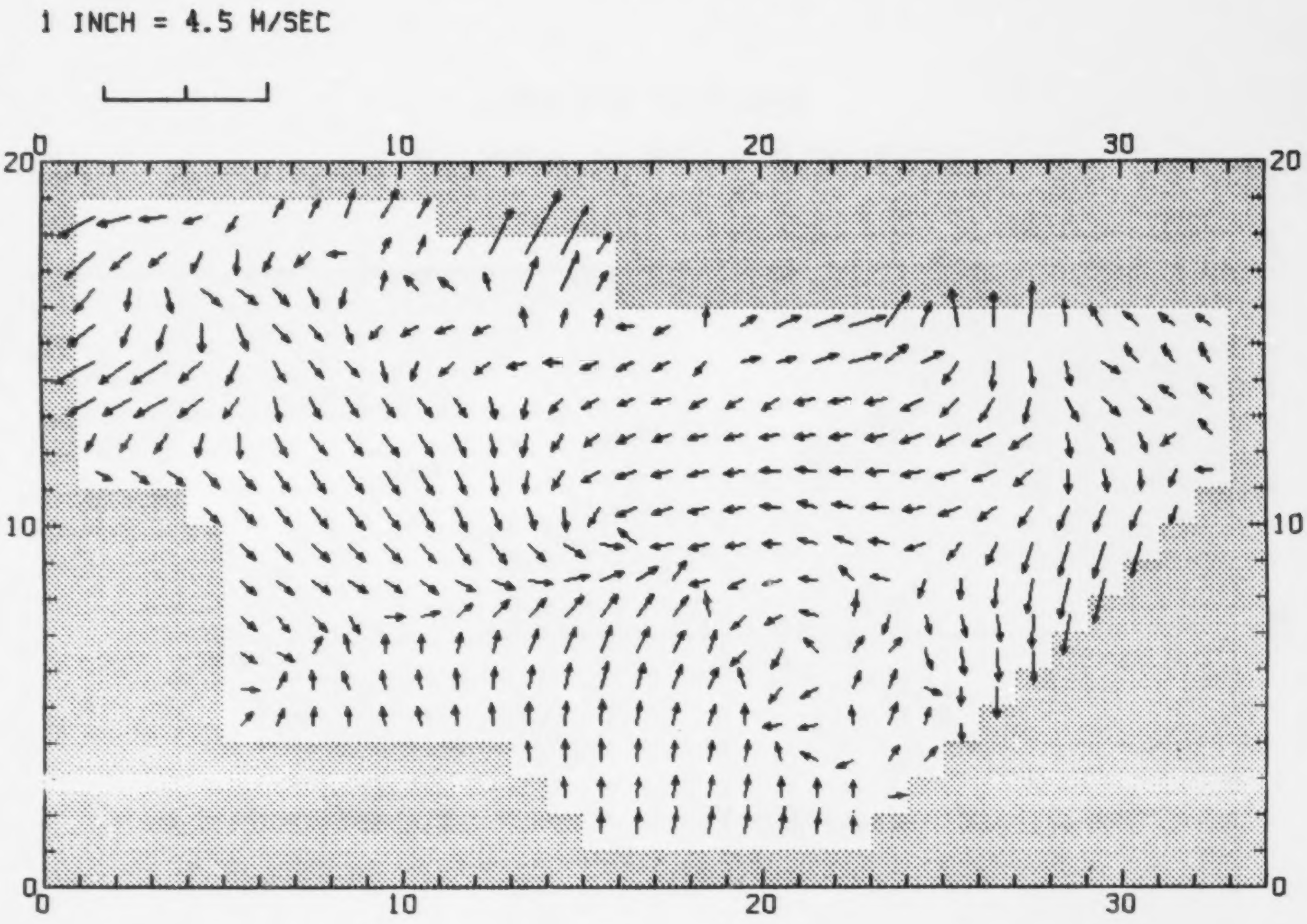
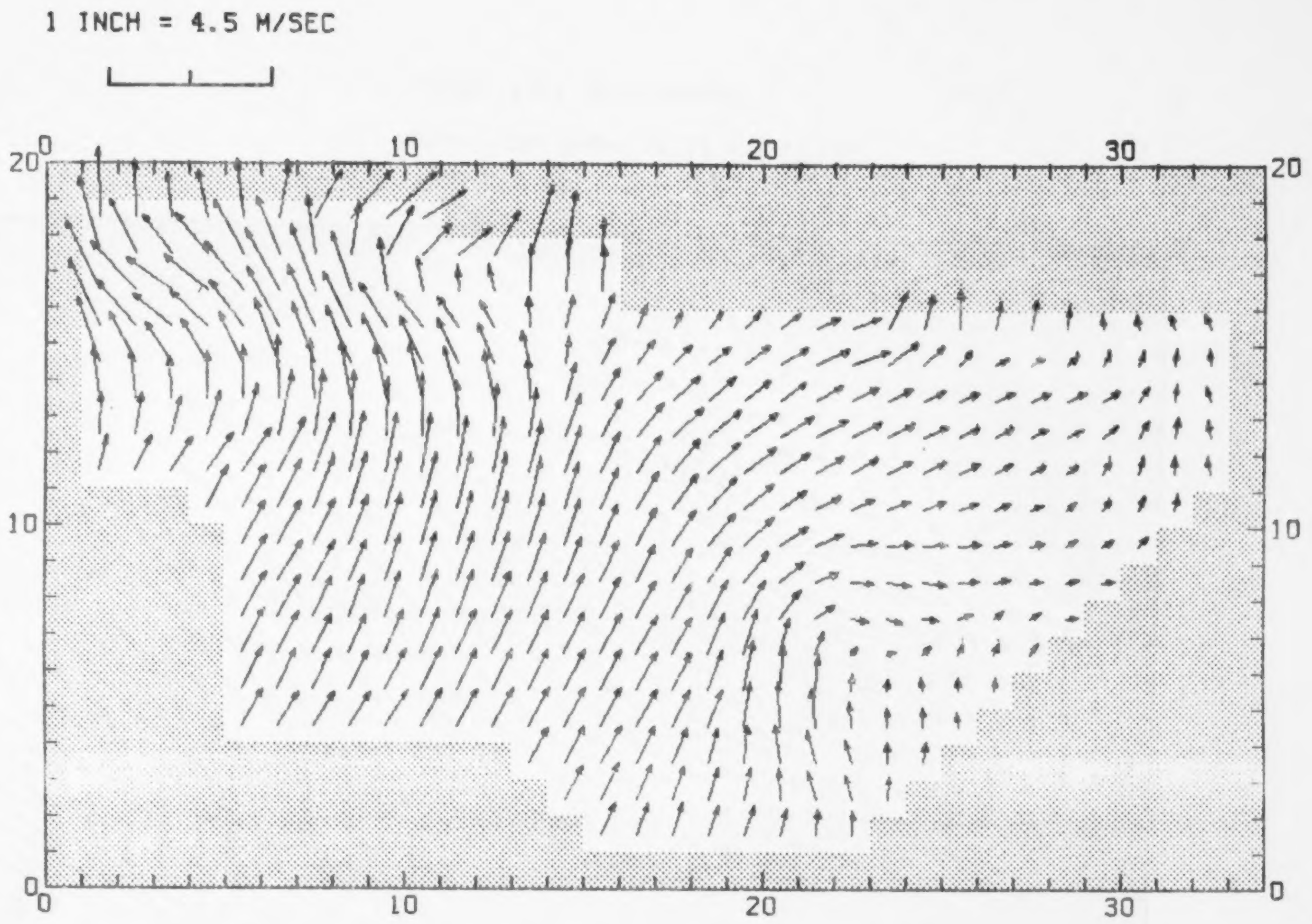
(c) Between the Hours of 15 and 16 LST

FIGURE A-12 (Concluded)



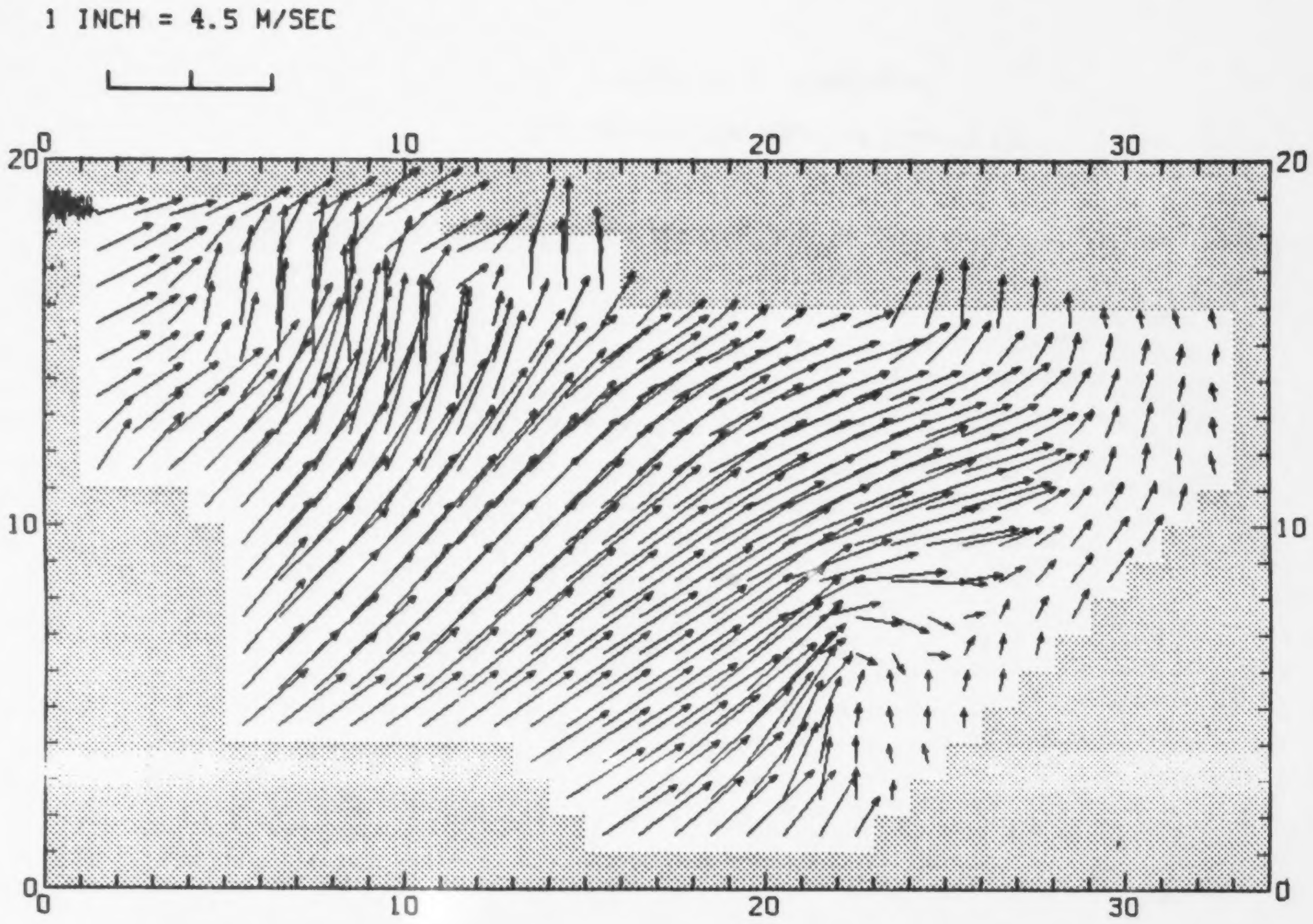
(a) Sensitivity Case 3 Between the Hours of 4 and 5 LST

FIGURE A-13. WIND FIELD AT GROUND LEVEL, 26 JUNE 1974



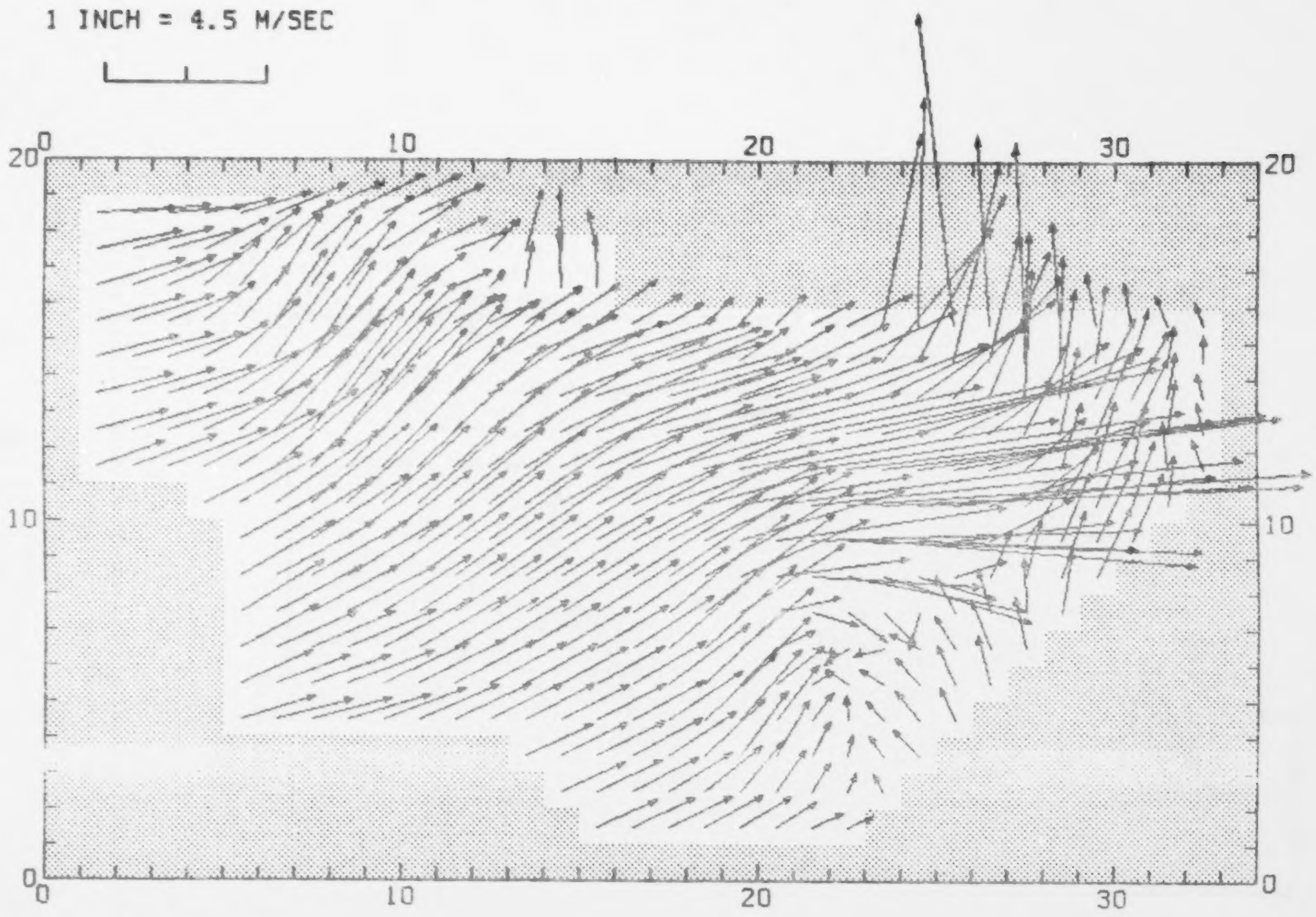
(b) Between the Hours of 8 and 9 LST

FIGURE A-13 (Continued)



(c) Between the Hours of 11 and 12 LST

FIGURE A-13 (Continued)



(d) Between the Hours of 18 and 19 LST

FIGURE A-13 (Concluded)

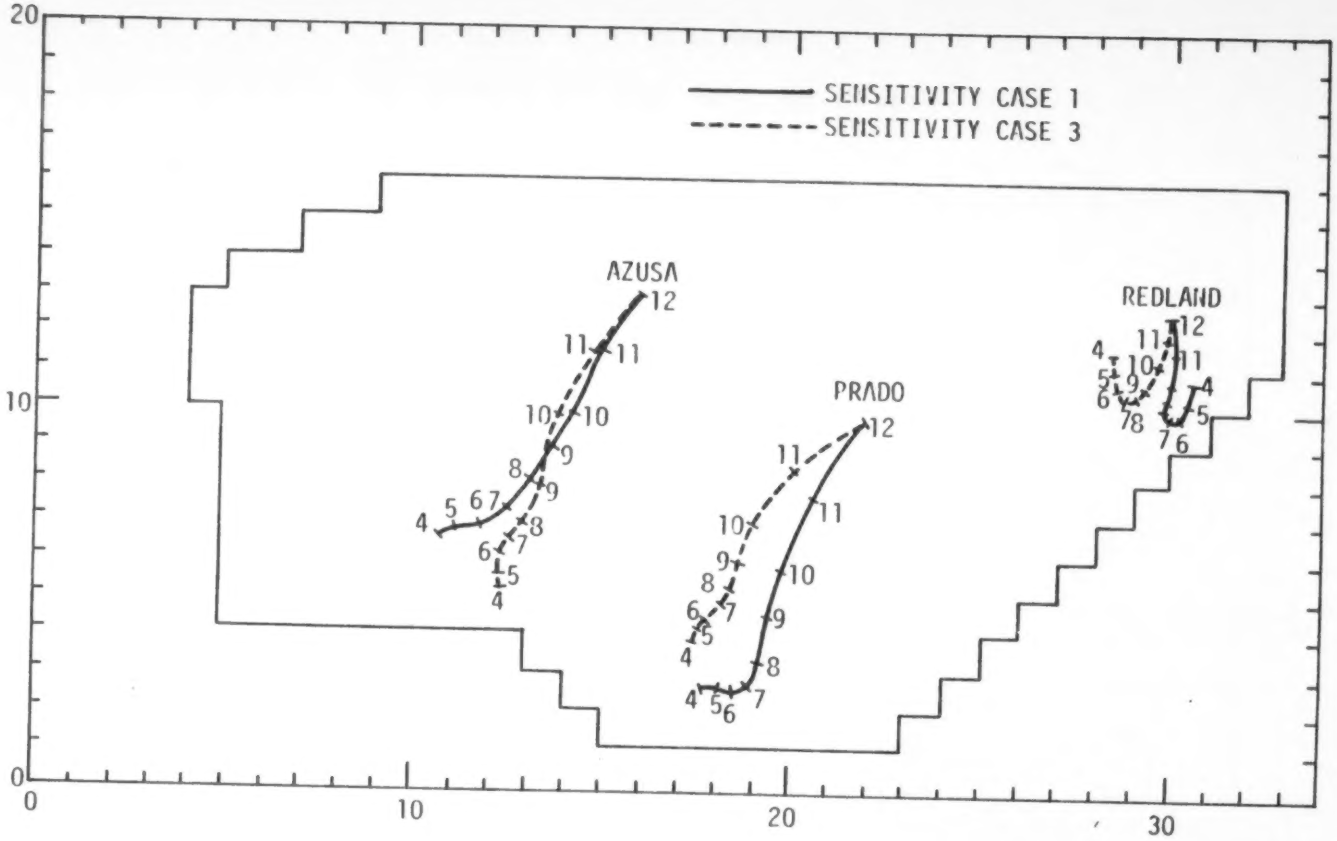


FIGURE A-14. AIR PARCEL TRAJECTORIES: CASE 3--CASE 1

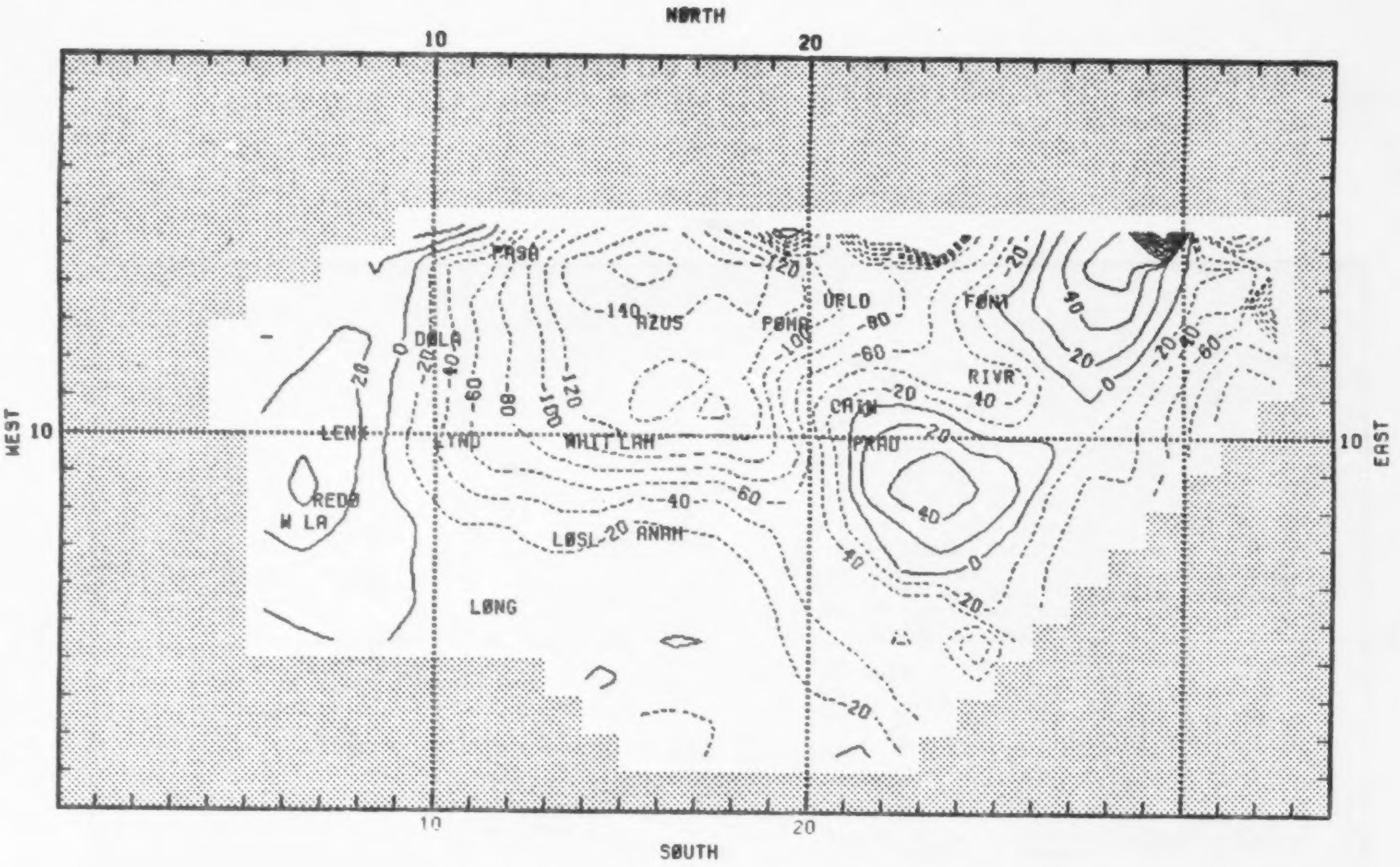

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FIGURE A-15. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 3--
BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST

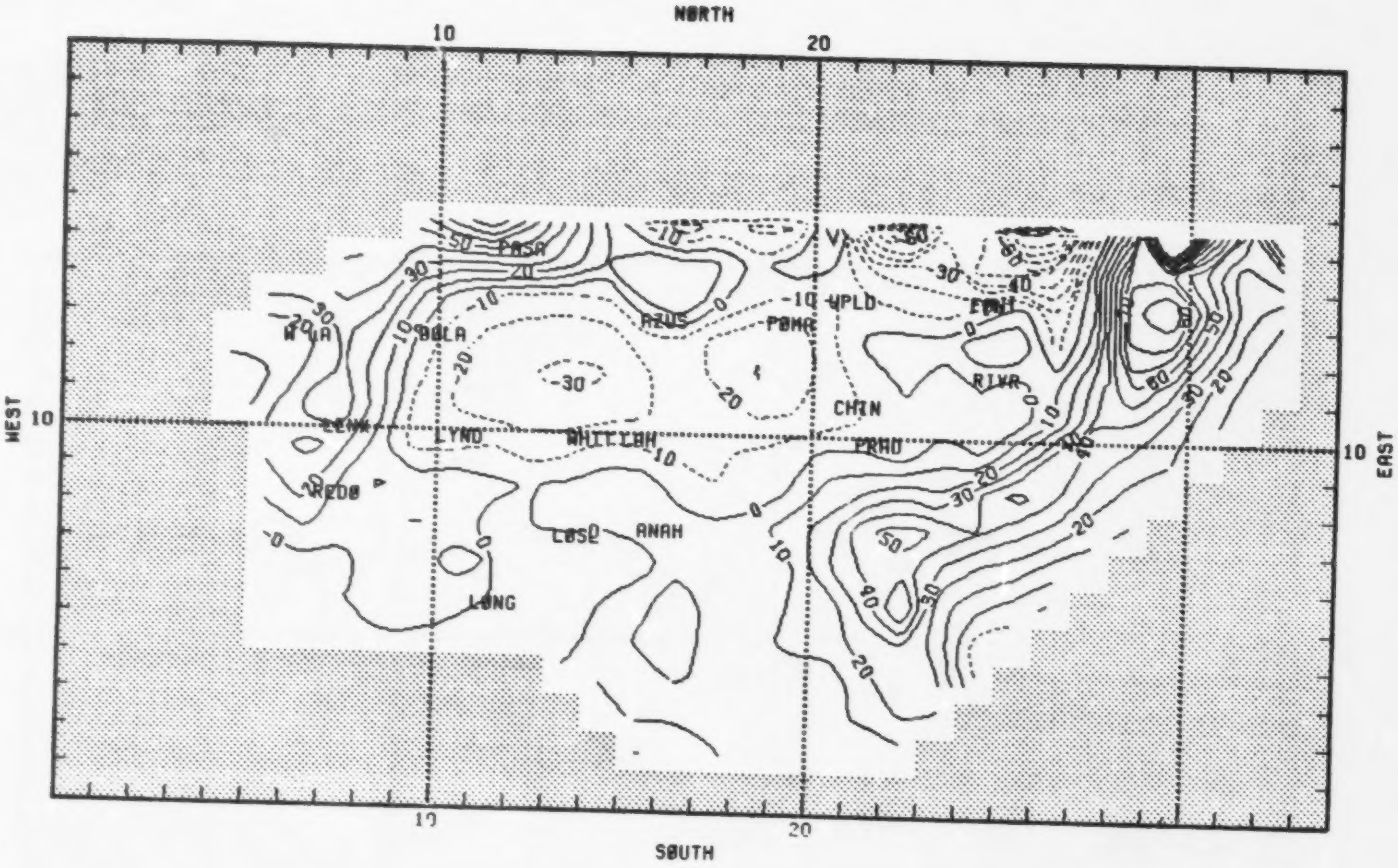
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FIGURE A-16. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 3--CASE 1 BETWEEN THE HOURS OF 4 and 19 LST was shown in figure A-13 that the wind flow is strongly perturbed in this part of the basin, and this may explain the large ozone variations. Ozone profiles at nine air quality monitoring stations are presented in figure A-17 for this sensitivity case and for the base case. Profiles for the sensitivity case are similar to those of case 1 at most stations. A higher ozone peak at Pasadena may result from lower mixing depths, though a different air trajectory may also be a possible factor. The profile at Redlands is very different from the profile of case 1 (see figure A-5) owing to the strong perturbation in the wind field in this part of the basin. Higher wind velocities probably constitute one of the factors leading to lower ozone levels in mid basin (e.g., Azusa and Pomona).

4) Conclusions

It appears that surface meteorological data affect mixing depths, wind direction (especially at the airshed boundaries), and wind speeds. These perturbations lead to some deviations in the ozone levels, but the overall effect is not as large as that caused by the reduction of upper air meteorological data.

These results depend on the nature of the wind model. The wind field is obtained by solving a boundary value problem for a potential function. Therefore, the results should be more sensitive to meteorological data located at the boundaries of the airshed than to the intensity of data in mid basin, for example. Upper air meteorological data have a strong effect on the wind field with those meteorological conditions, and it has been shown that perturbations in the wind field caused by a reduction in surface data were larger near the airshed boundaries.

Notable perturbations are observed in the mixing depths, and their effects may be larger than in case 1, though the relative importance of perturbations in the mixing height and wind field is difficult to evaluate.

d. Model Sensitivity to Surface Meteorological Data--Simulation of 4 August 1975

In this sensitivity simulation, surface and upper air meteorological data have been reduced. To evaluate the effect of a reduction in surface meteorological data, comparisons will be made with case 2 (reduced upper air meteorological data) and the August base case.

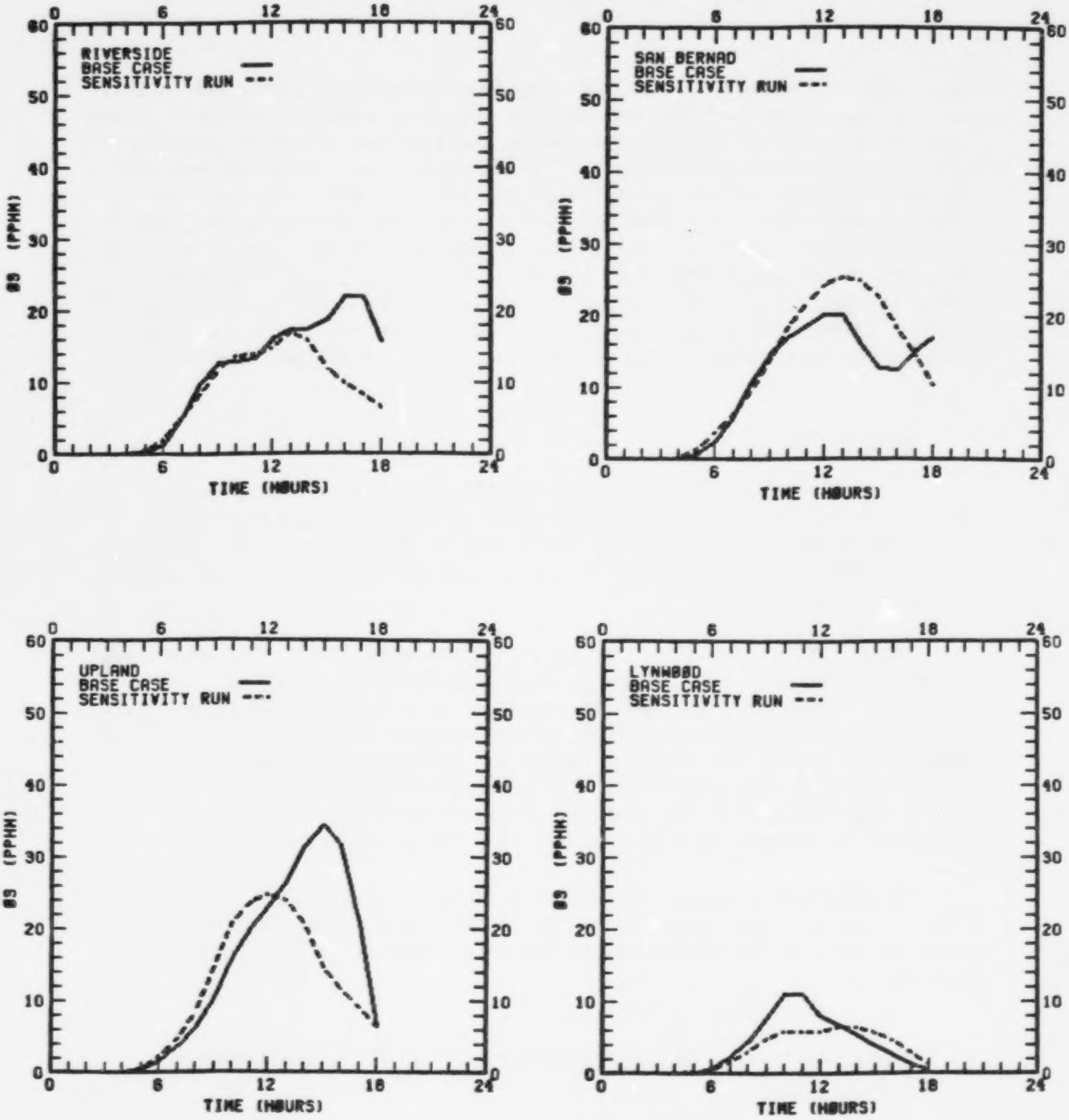


FIGURE A-17. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 3

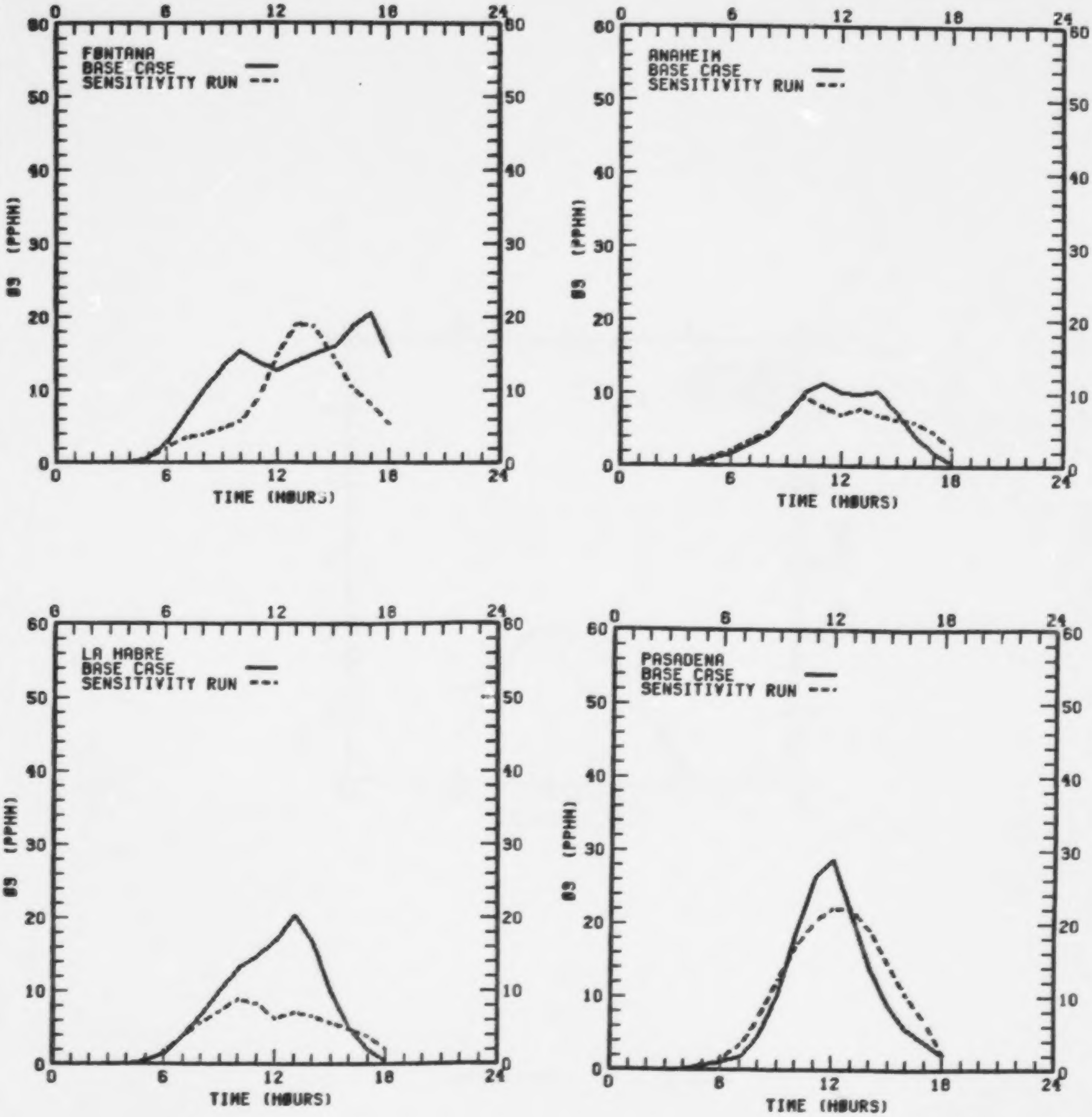


FIGURE A-17 (Continued)

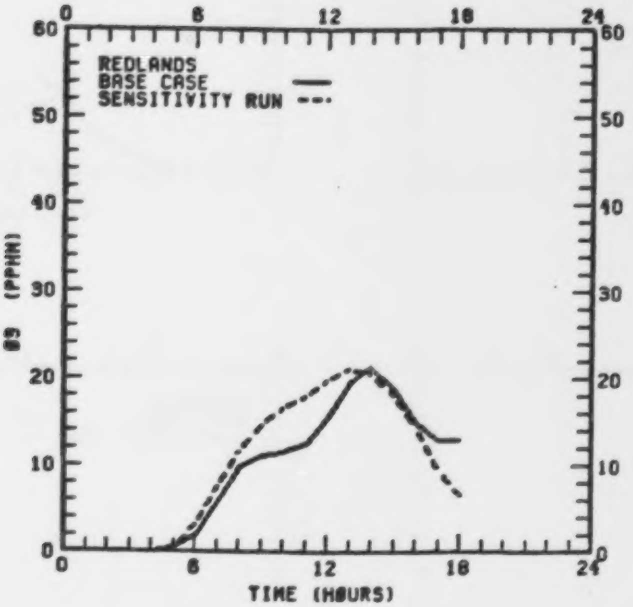


FIGURE A-17 (Concluded)

1) General Sensitivity Measures

Some measures of the general sensitivity of the model are listed in tables A-6 and A-7 for comparisons with the base case and case 2.

The absolute deviations are of the same order as those obtained in case 2. However, the signed deviations are larger (see table A-3). In general, ozone levels are lower in this case than in case 2 and, therefore, than in the 4 August 1975 base case. This effect appears clearly in the dosage, which is much lower than in case 2 or the base case. The dosage-normalized difference is comparable to that obtained with the 26 June 1974 meteorological conditions.

Ozone peak levels are also affected by a reduction in surface meteorological data, and the overall maximum ozone level and the station maximum ozone statistics show a decrease in ozone concentrations.

Although spatial and temporal correlations depend on the statistics considered (ozone level, grids or stations), they are closer to case 1 with these meteorological conditions than with the 26 June 1974 conditions (see table A-3).

2) Sensitivity of Model Input Variables to Input Data

The mixing height and wind field are the only variables considered here, since estimation of eddy diffusivities is not heavily data dependent.

Mixing depths for the hours of 0400 to 0500, 1100 to 1200, and 1800 to 1900 L.S.T are shown in figure A-18. When compared with the mixing depths of case 2 (see figure A-6), it appears that the mixing height is slightly higher in this case around Pasadena and Whittier (20 to 40 m), lower around Anaheim (20 to 40 m), and similar to case 2 in the eastern part of the basin (e.g., Prado).

The wind field is shown in figure A-19 for various hours of simulation. There are no important perturbations between this wind field and the wind fields of case 2 or the base case (see figure A-8), as shown by the comparison of air parcel trajectories shown in figure A-20. There is a slight deviation for the Prado air parcel in the early morning hours, but it is minor when compared to the deviations observed with the 26 June 1974 meteorological conditions (see figures A-3 and A-14).

TABLE A-6. GENERAL SENSITIVITY MEASURES--CASE 4 VS. BASE CASE

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	$O_3 > 12$ pphm	$O_3 > 20$ pphm	$O_3 > 12$ pphm	$O_3 > 20$ pphm
Signed deviation	-0.146	-0.073	-0.107	-0.165
Absolute deviation	0.189	0.104	0.198	0.187
Temporal correlation	0.799	0.682	0.737	0.263
Spatial correlation	0.648	0.937	0.450	0.608

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	0.988	0.755
Peak level (pphm):		
Sensitivity case	26.0	28.0
base case	26.3	37.0
Corresponding locations:		
Sensitivity case	Upland	27 - 15
base case	Pomona	30 - 16

TABLE A-6 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.143	0.121
Peak time lag (hrs)	0.825	0.812

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
-0.244	6,625	8,750

TABLE A-7. GENERAL SENSITIVITY MEASURES--CASE 4 VS. CASE 2

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	$O_3 > 12$ pphm	$O_3 > 20$ pphm	$O_3 > 12$ pphm	$O_3 > 20$ pphm
Signed deviation	-0.061	-0.076	-0.061	-0.093
Absolute deviation	0.098	0.084	0.110	0.110
Temporal correlation	0.907	0.986	0.922	0.923
Spatial correlation	0.894	0.572	0.835	0.697

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ case 2 ratio	0.953	0.900
Peak level (pphm):		
Sensitivity case	26.0	28.0
Case 2	27.3	31.1
Corresponding locations:		
Sensitivity case	Upland	27 - 15
Case 2	Upland	11 - 16

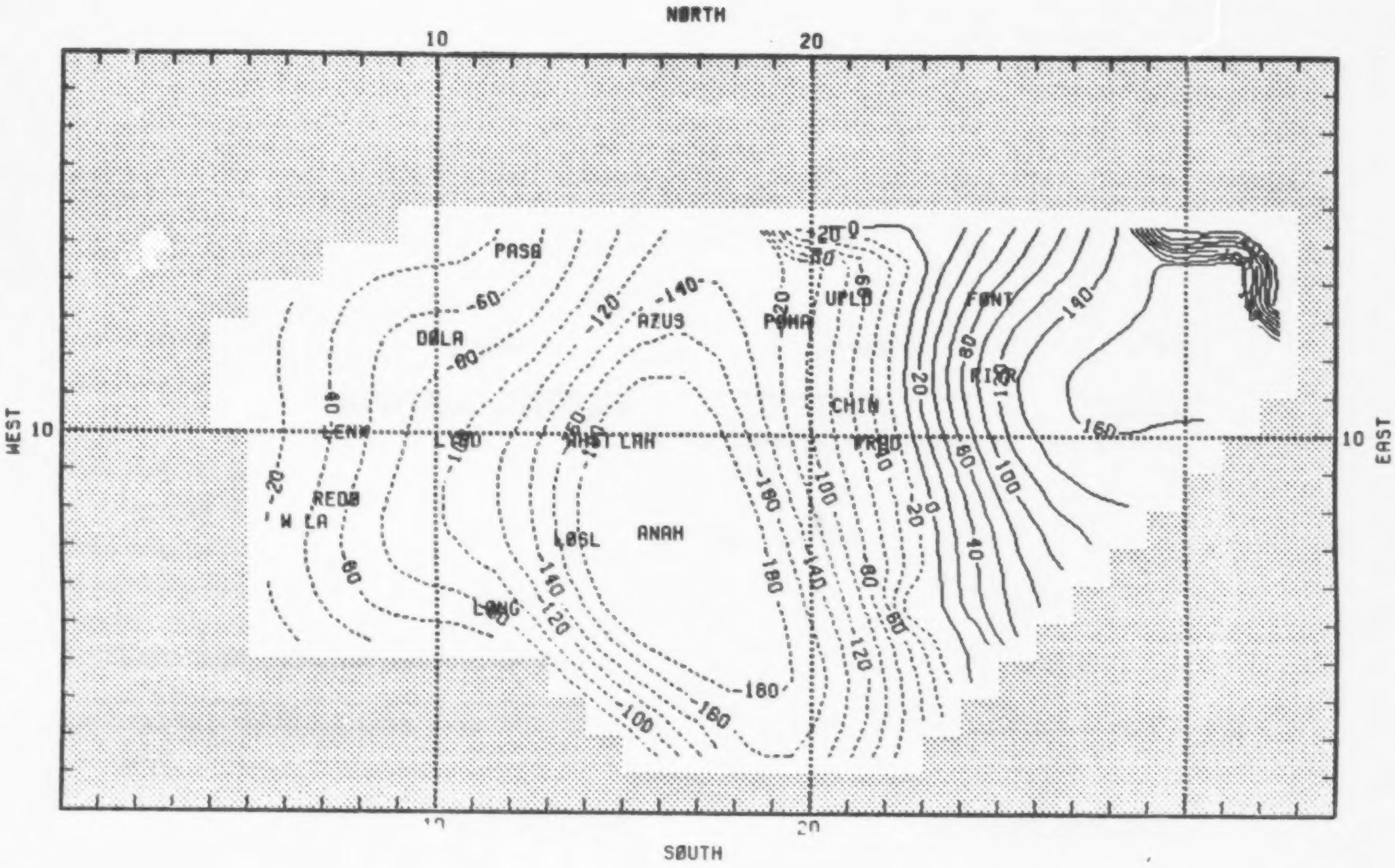
TABLE A-7 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.09	0.069
Peak time lag (hrs)	0.30	0.310

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Case 2 (km^2)
-0.230	6,625	8,600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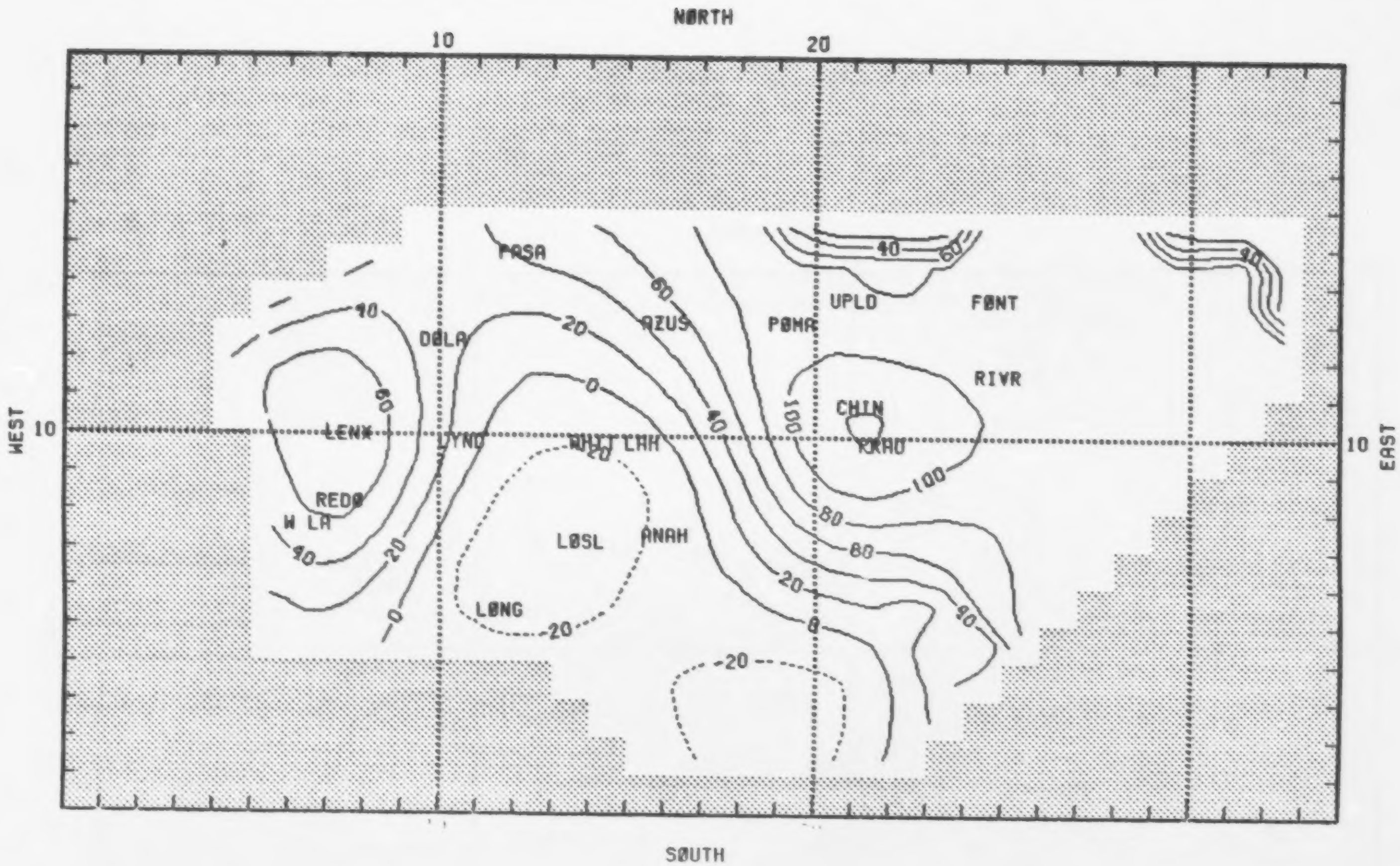
(a) Between the Hours of 4 and 5 LST

FIGURE A-18. MIXING HEIGHT DIFFERENCE (m): CASE 4--BASE CASE



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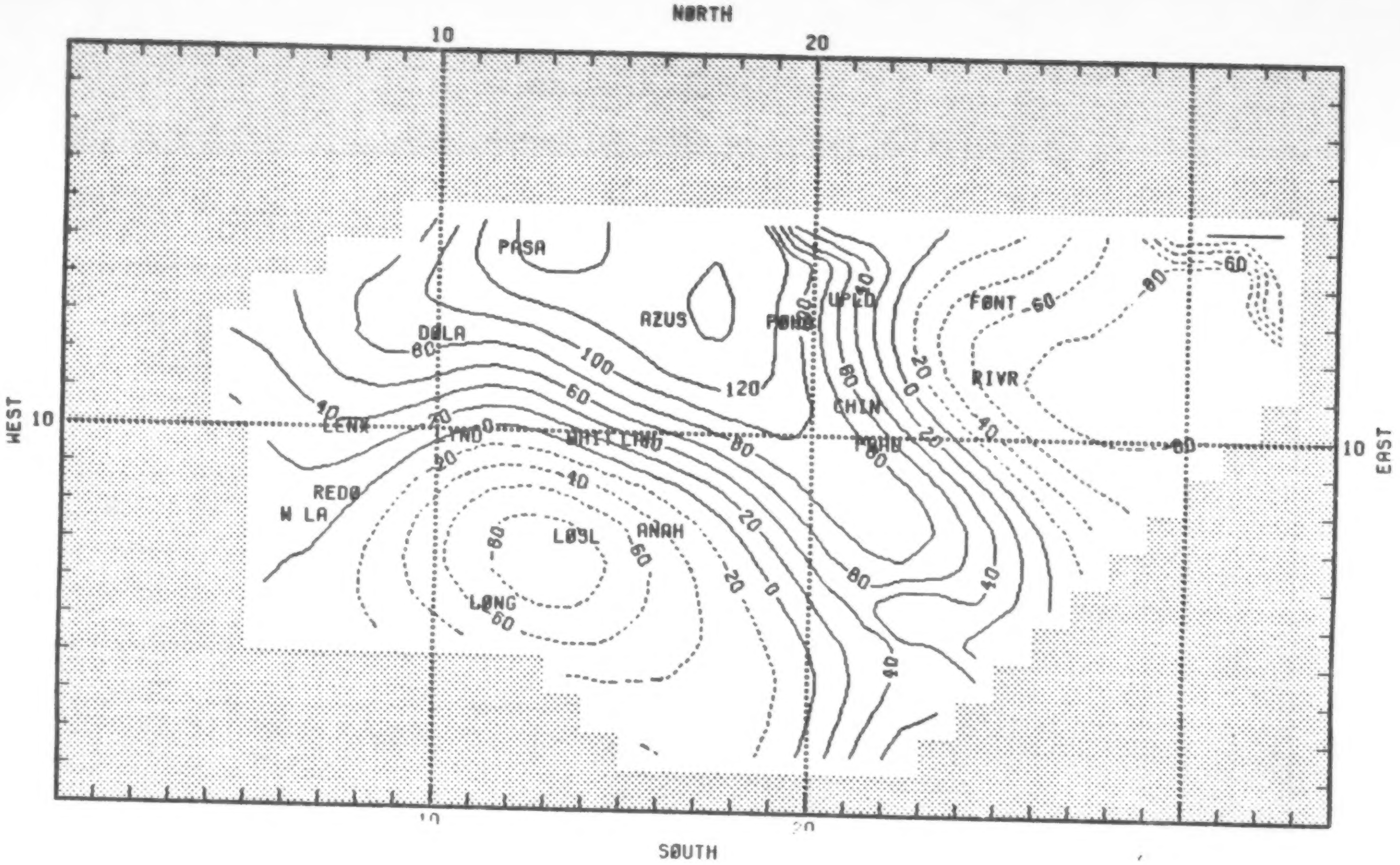
(b) Between the Hours of 11 and 12 LST

FIGURE A-18 (Continued)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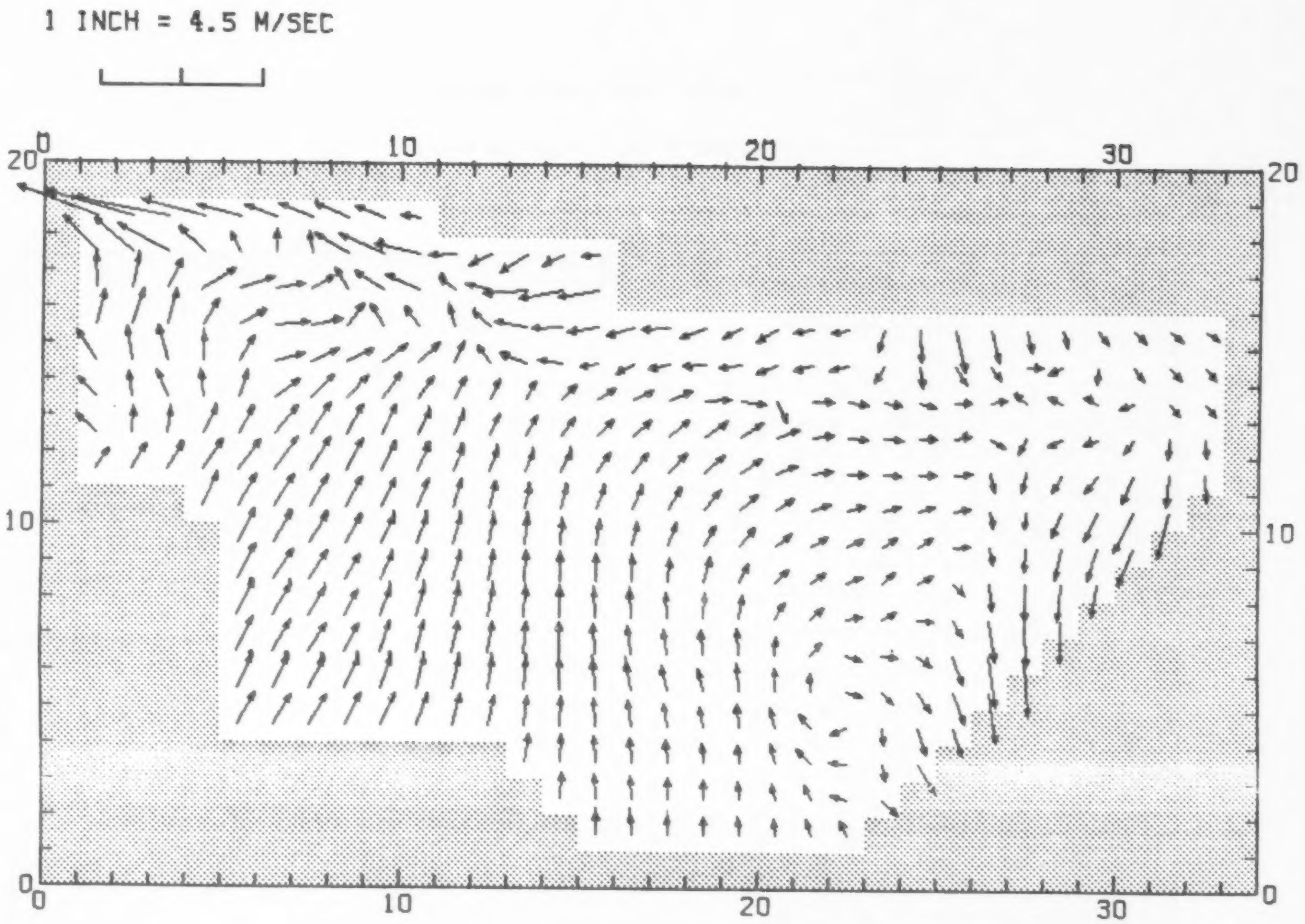
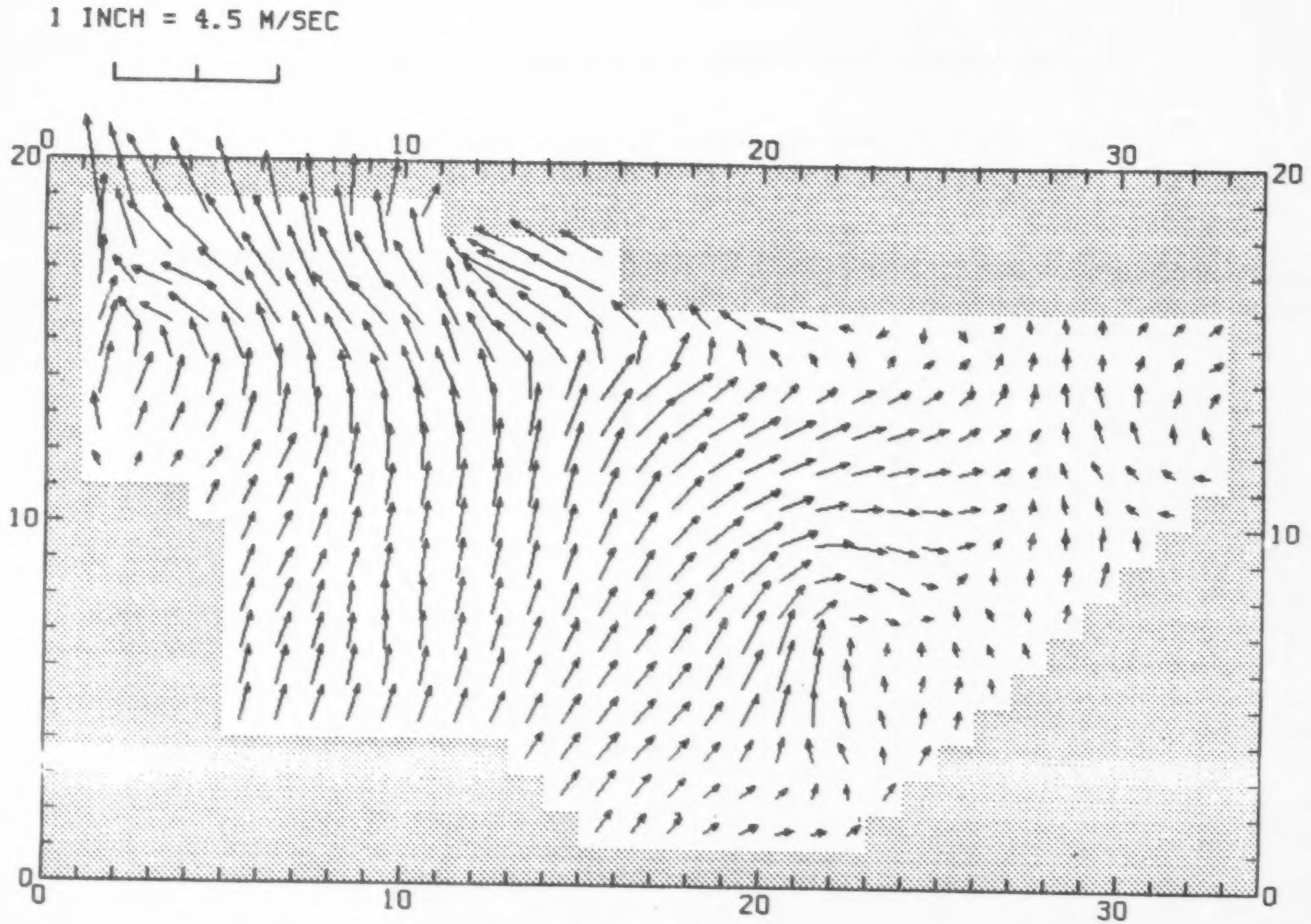
(c) Between the Hours of 18 and 19 LST

FIGURE A-18 (Concluded)



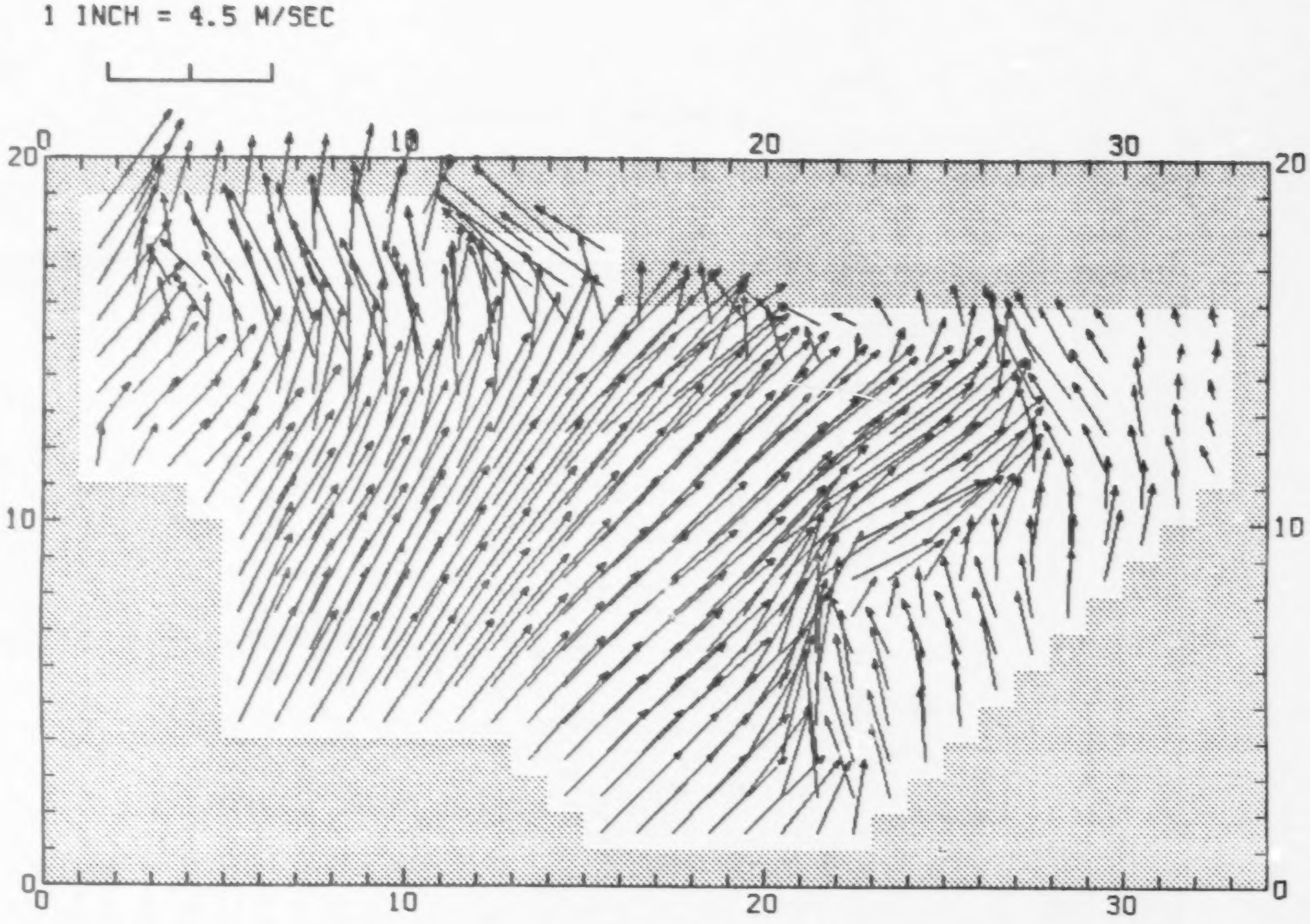
(a) Sensitivity Case 14 Between the Hours of 4 and 5 LST

FIGURE A-19. WIND FIELD AT GROUND LEVEL, 4 AUGUST 1975



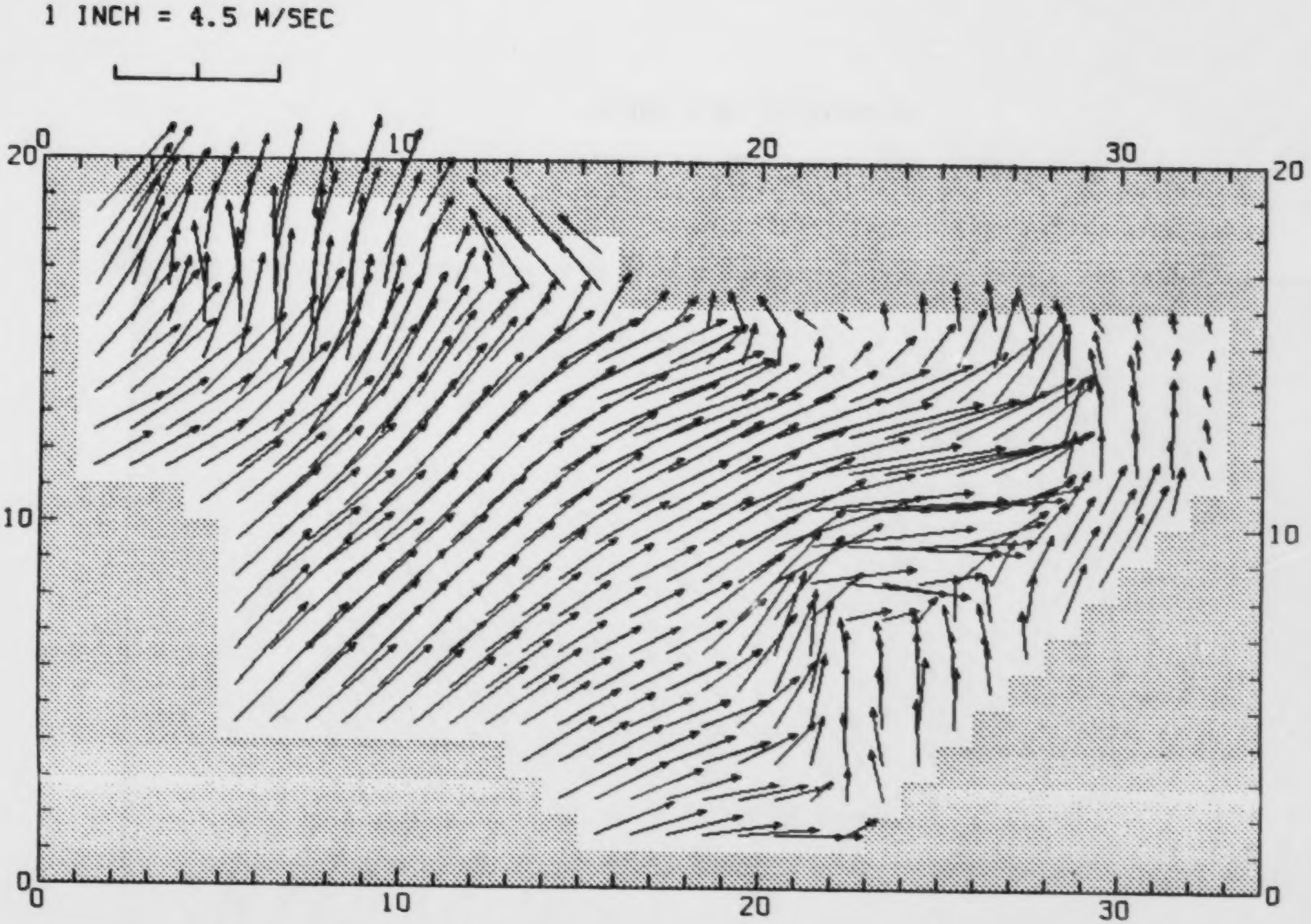
(b) Between the Hours of 8 and 9 LST

FIGURE A-19 (Continued)



(c) Between the Hours of 11 and 12 LST

FIGURE A-19 (Continued)



(d) Between the Hours of 18 and 19 LST

FIGURE A-19 (Concluded)

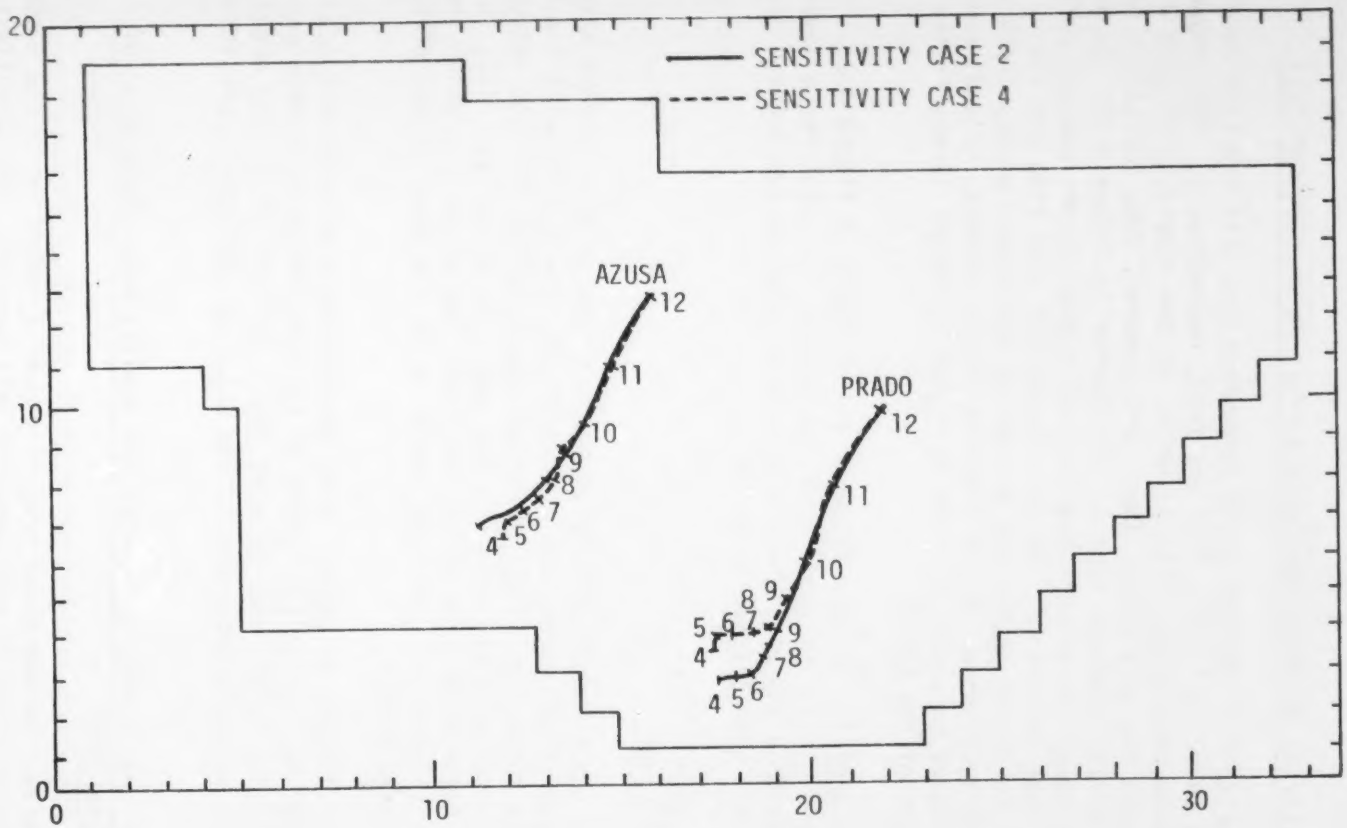


FIGURE A-20. AIR PARCEL TRAJECTORIES: CASE 4--CASE 2

3) Sensitivity of Ozone Levels to Surface Meteorological Data

Comparisons of maximum ozone concentrations with the base case and case 2 are shown in figures A-21 and A-22, respectively. The comparison with the base case shows pattern similar to the isopleths of case 2 compared with the base case. There are, however, some variations between this sensitivity case and case 2, that appear in figure A-22. Ozone levels are lower in northern midbasin and higher in the eastern part for this case than for case 2. By considering the wind flow and the variations in mixing depth, one may relate the higher mixing depth around Whittier to lower ozone levels downwind (Azusa, Pomona, Upland) and the lower mixing depth around Anaheim to higher pollutant levels in the eastern part of the basin.

Ozone profiles are presented at six stations in figure A-23. Profiles are similar to those obtained in case 2, except for a lower ozone peak at Pasadena and a slightly higher peak level at San Bernardino, both of which have been discussed earlier.

4) Conclusions

Under the 4 August 1975 meteorological conditions, surface meteorological data affect mainly the mixing height, whereas the wind field is not notably perturbed. The same effect was observed with the reduction of upper air meteorological data for the same simulation day. This is an important difference from the 26 June 1974 simulations, in which the wind field was strongly perturbed and seemed to be the major factor affecting the model predictions.

In conclusion, it appears that the influence of meteorological data on the model depends on the nature of the meteorological conditions and that the mixing height and the wind field may both affect the model predictions strongly according to the existing atmospheric conditions.

e. Model Sensitivity to Surface Air Quality Data--Simulation of 26 June 1974

The effect on the model predictions of a reduction in the number of air quality stations is considered in this section. The sensitivity of the model to surface air quality data (case 5-1) is considered first. This is followed by consideration of sensitivity of the model (case 5-2) to a reduction in surface air quality data (as in case 5-1) and to a reduction in upper air and surface meteorological data (as in case 3).

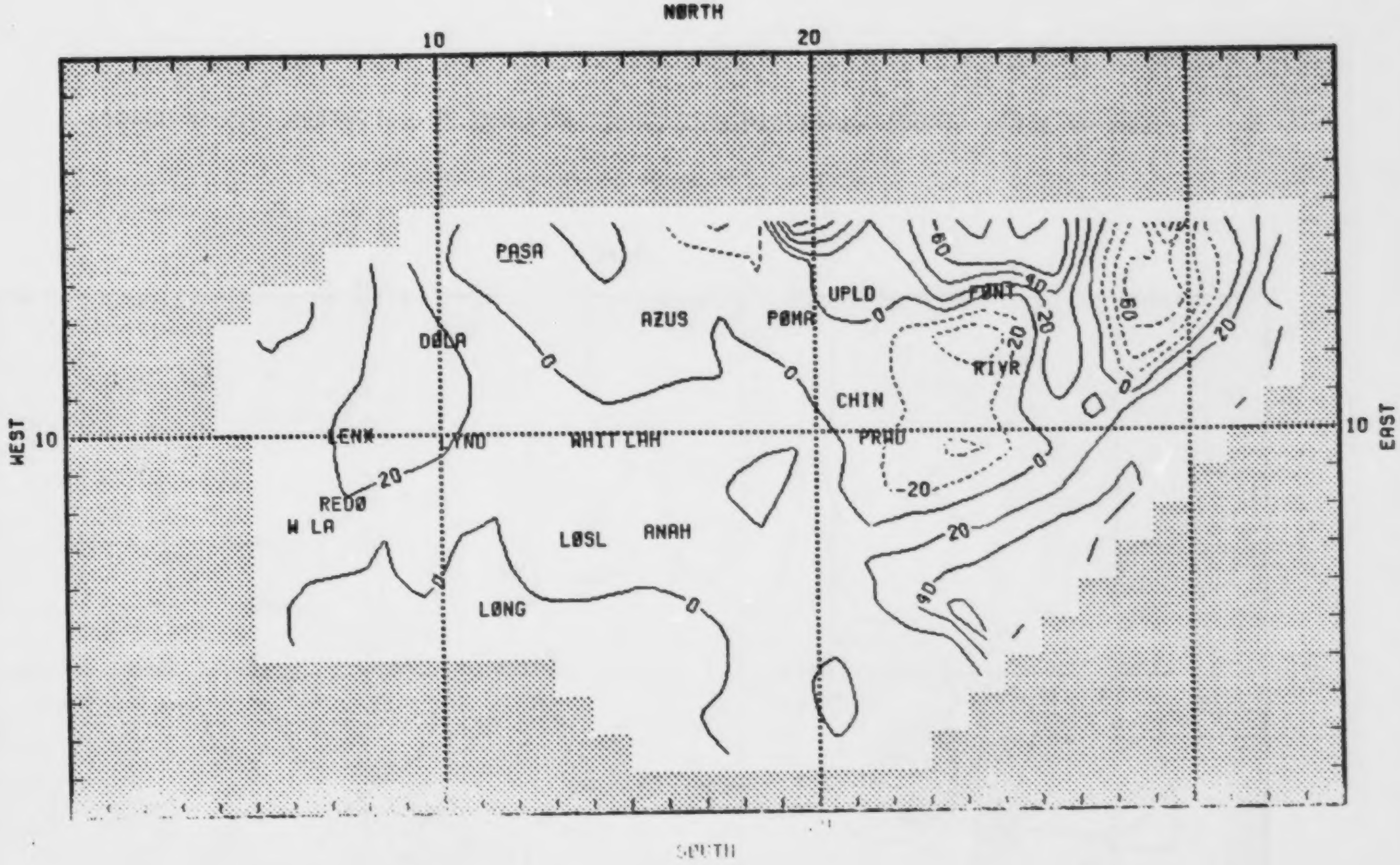

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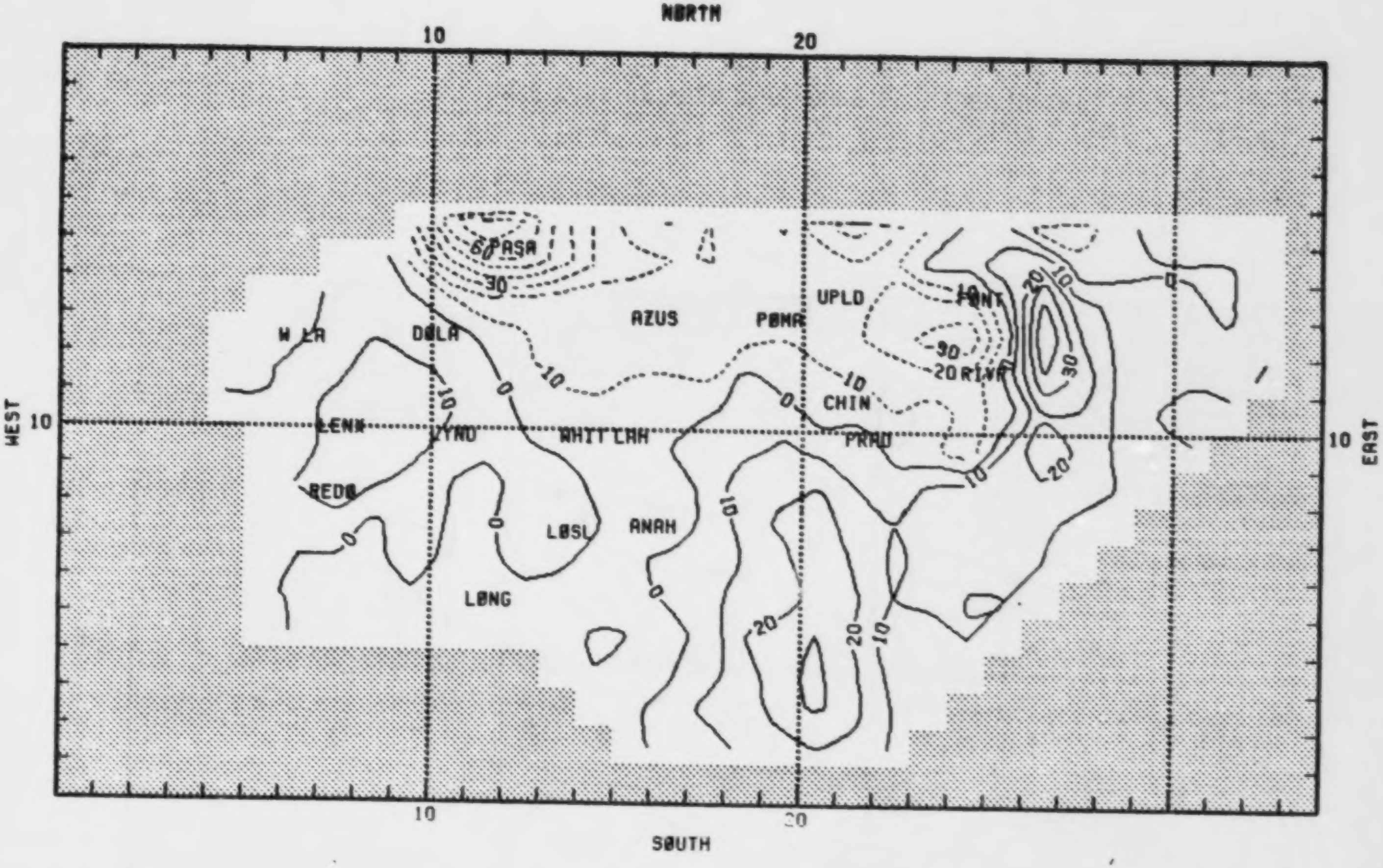
FIGURE A-21. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 4--BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST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Between the Hours of 4 and 13 LST

FIGURE A-22. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 4--CASE 2

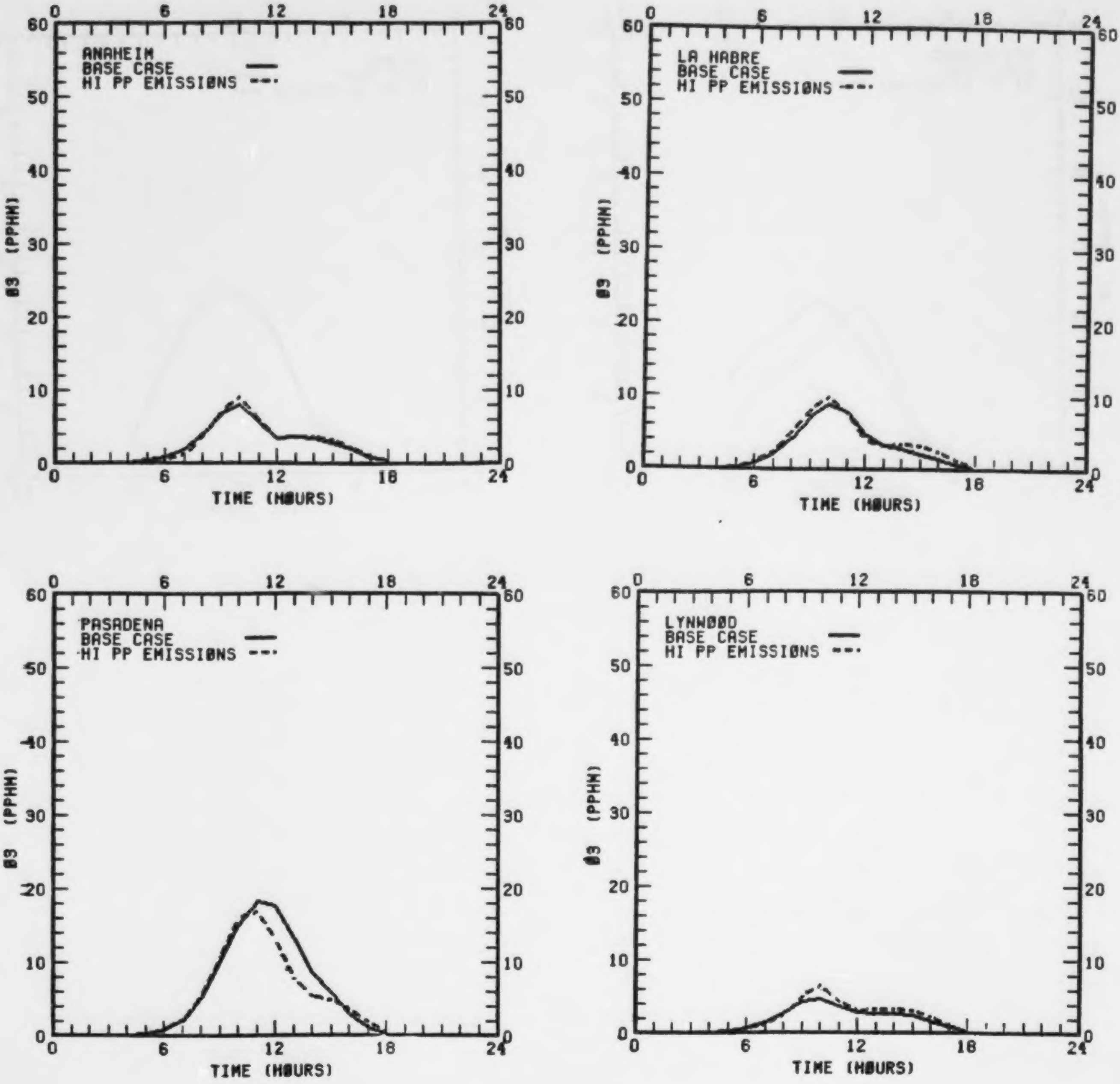
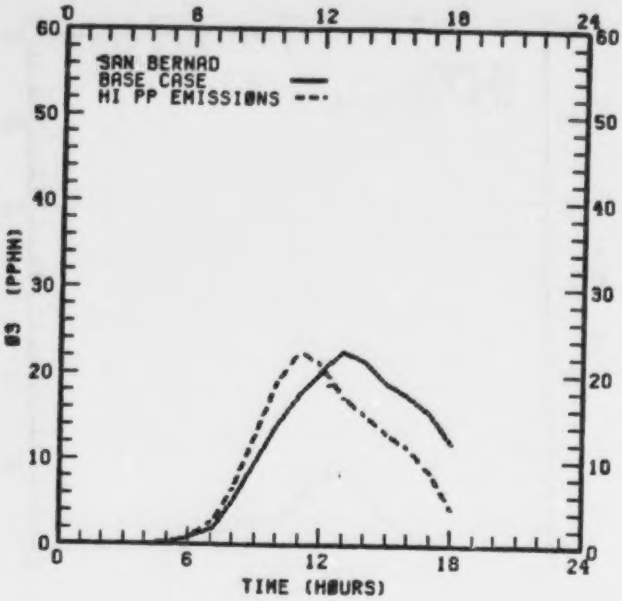


FIGURE A-23. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: Case 4



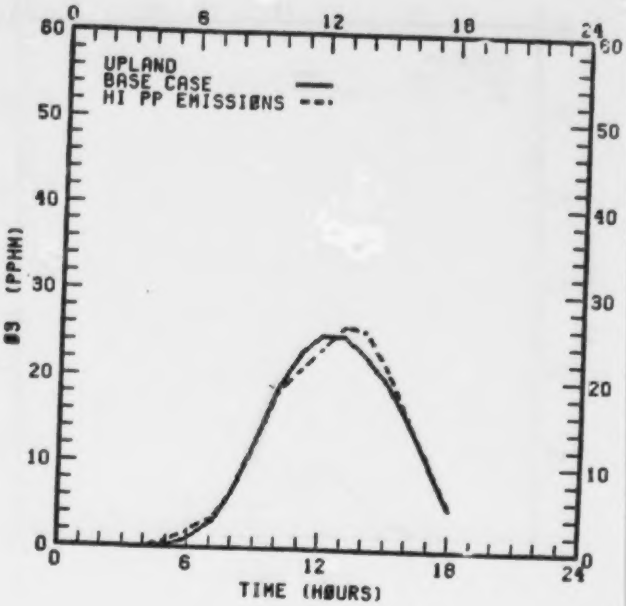


FIGURE A-23 (Concluded)

1) General Sensitivity Measures

Some measures of the general sensitivity of the model to a reduction in air quality data and to a reduction in both meteorological and air quality data are presented in tables A-8 and A-9, respectively.

The results presented in table A-8 show that the model is not very sensitive to the reduction in surface air quality data. The ozone deviations, peak level difference, and dosage difference are small. There is, however, a large difference between the maximum ozone statistic for all stations and that for downwind stations. This fact suggests that coastal stations are more sensitive to air quality data reduction than are downwind stations. The temporal and spatial correlations are high (above 0.965).

The results presented in table A-9 (reduction in meteorological and surface air quality data) are similar to the results presented in table A-8 (reduction in meteorological data only). This is consistent with the results of table A-8, which indicate that the model is not very sensitive to surface air quality data. Ozone predictions of sensitivity case 5-2 are systematically lower than those of case 3. The combination of meteorological and air quality data reduction is, therefore, not additive, since no overall decrease in ozone levels is observed in case 5-1. This is particularly apparent when comparing the dosages. Finally, the pattern observed in case 5-1 for the maximum ozone statistics of all stations and downwind stations also appears in case 5-2.

2) Sensitivity of Model Input Variables to Input Data

The reduction in surface air quality data affects the initial and boundary conditions for ozone, carbon monoxide, nitrogen oxides, and hydrocarbons. The perturbation in the model equations will depend in part on the spatial distribution of the air monitoring stations in the base case and in the sensitivity case. The locations of the stations have been presented in chapter three.

3) Sensitivity of Ozone Levels to Surface Air Quality Data

Isopleths of maximum ozone deviations are presented in figures A-24 and A-25 for the sensitivity cases 5-1 and 5-2, respectively. It appears in figure A-24 that the southwestern part of the basin presents lower ozone levels in case 5-1 than in the base case. Higher ozone levels occur west of Pasadena, and the two effects compensate each other in most of the

TABLE A-8. GENERAL SENSITIVITY MEASURES--CASE 5 VS. CASE 3

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	$O_3 > 12$ pphm	$O_3 > 20$ pphm	$O_3 > 12$ pphm	$O_3 > 20$ pphm
Signed deviation	0.000	0.003	0.006	0.010
Absolute deviation	0.028	0.022	0.032	0.032
Temporal correlation	0.990	0.990	0.988	0.984
Spatial correlation	0.986	0.986	0.980	0.965

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	0.997	0.982
Peak level (pphm):		
Sensitivity case	35.4	38.2
Base case	35.5	38.9
Corresponding locations:		
Sensitivity case	Azusa	19 - 15
Base case	Azusa	33 - 14

TABLE A-8 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.061	0.031
Peak time lag (hrs)	0.52	0.0

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
0.048	10,475	10,000

TABLE A-9. GENERAL SENSITIVITY MEASURES--CASE 5 VS. BASE CASE

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	O_3 > 12 pphm	O_3 > 20 pphm	O_3 > 12 pphm	O_3 > 20 pphm
Signed deviation	-0.208	-0.390	-0.253	-0.416
Absolute deviation	0.329	0.402	0.355	0.459
Temporal correlation	-0.183	-0.402	-0.067	-0.253
Spatial correlation	0.313	-0.184	0.265	0.348

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	0.683	1.251
Peak level (pphm):		
Sensitivity case	24.2	48.6
Base case	35.5	38.9
Corresponding locations:		
Sensitivity case	San Bernardino	30 - 16
Base case	Azusa	33 - 14

TABLE A-9 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.293	0.266
Peak time lag (hrs)	2.25	1.93

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
-0.288	7,125	10,000

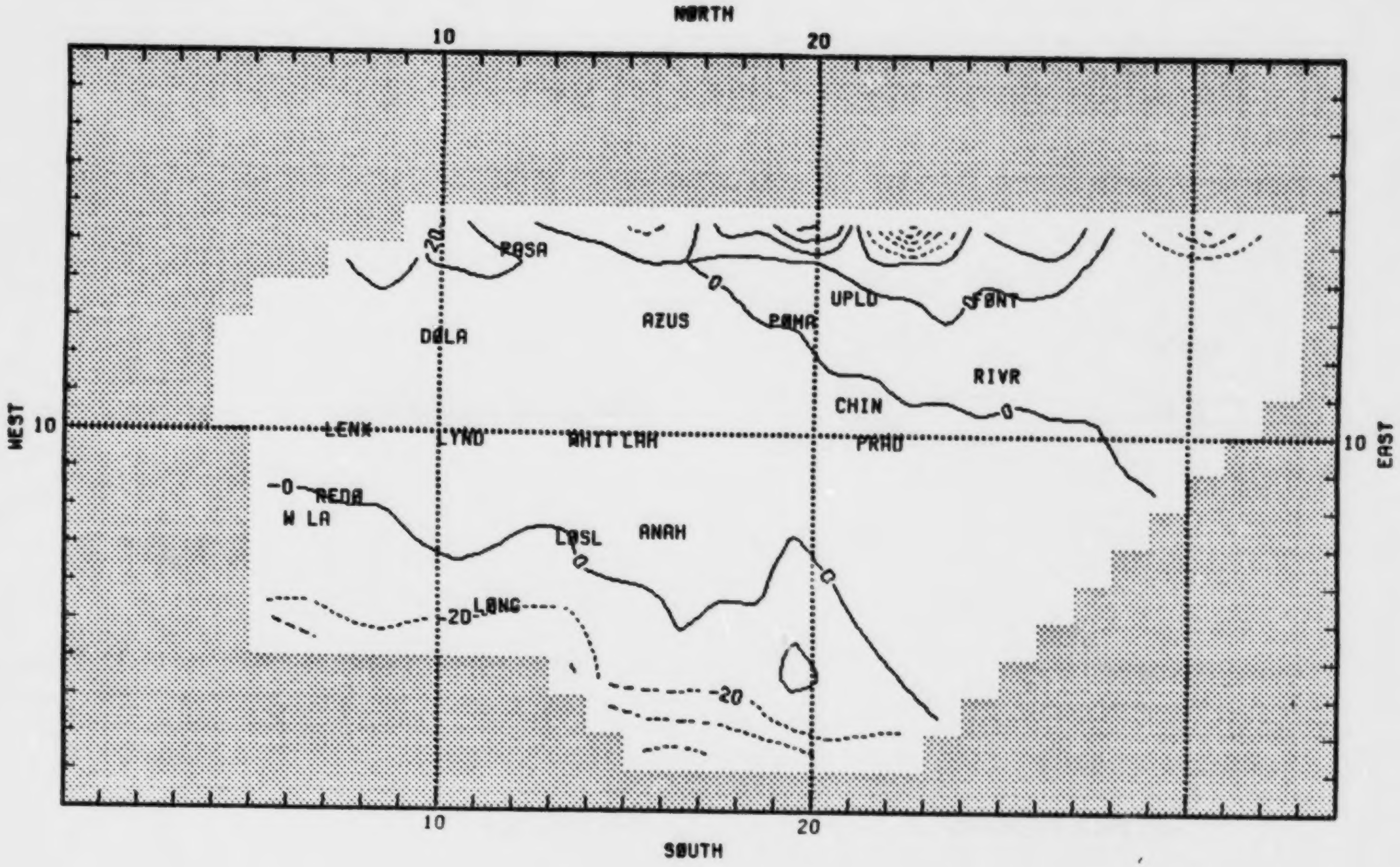

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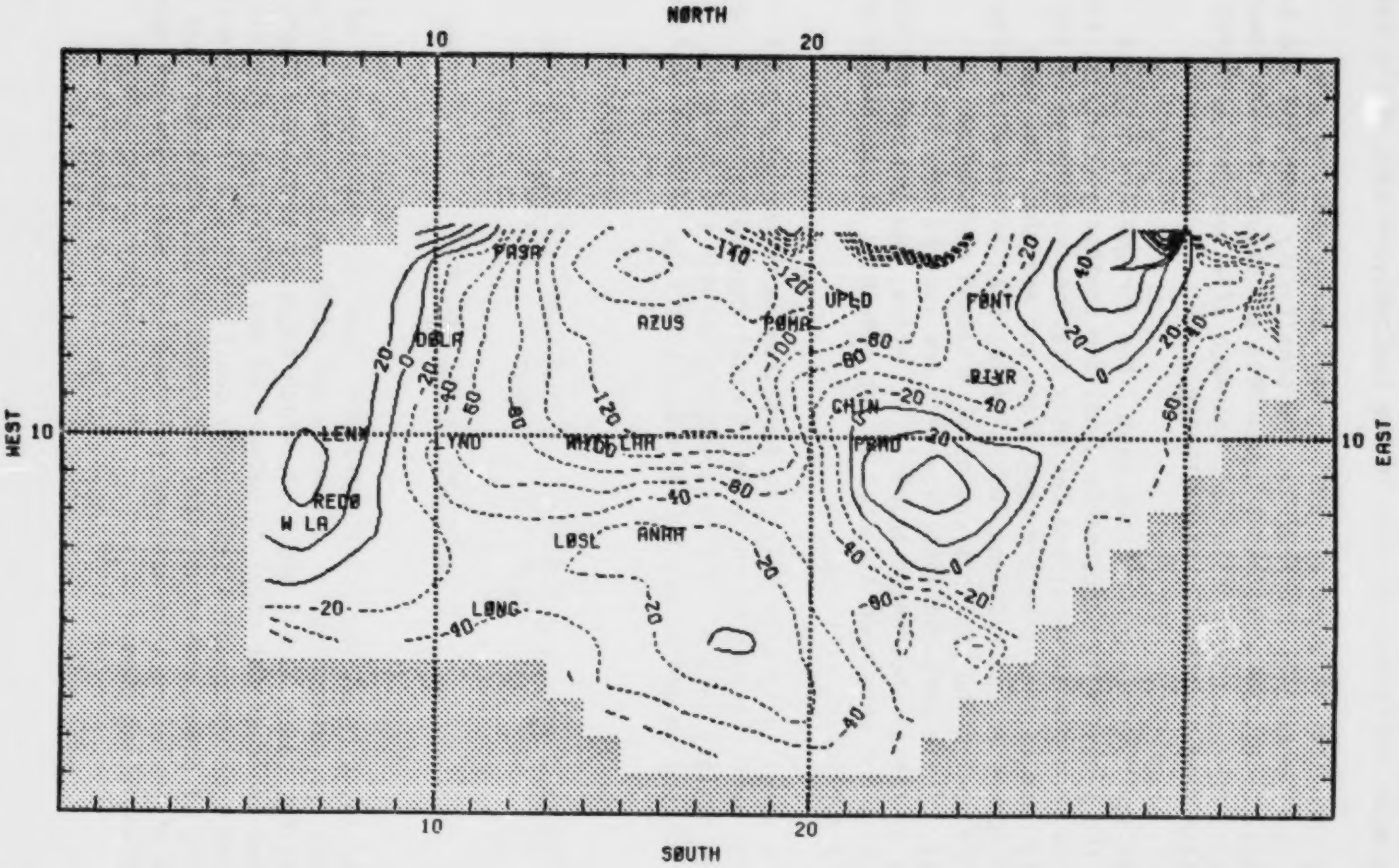
FIGURE A-24. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 5.1--BASE CASE BETWEEN THE HOURS OF 4 and 19 LST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WHIT
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ANAH
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-100
-80
-60
-40
-20
0
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40

FIGURE A-25. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 5.2-- BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST general sensitivity measures except in the maximum ozone statistics for all stations and for downwind stations, which showed the perturbation at the coastal air quality stations. Figure A-25 may be compared with figure A-24. The major difference is also in the southwestern part of the basin.

Ozone profiles at eight air quality monitoring stations are presented in figures A-26 and A-27 for the sensitivity cases 5-1 and 5-2, respectively. The coastal stations Costa Mesa and Laguna present lower ozone levels; other ozone profiles are not much affected when compared with the base case and case 3, respectively.

In the southwestern part of the basin, the air quality data are scarce in the sensitivity case, since winds are southerly (that is, there is an inflow into the airshed) and the only stations considered in the sensitivity case in this area are Long Beach and Anaheim. The same phenomenon occurs around Pasadena, where there is an inflow with westerly winds and no monitoring stations upwind of Pasadena or downtown Los Angeles. These perturbations, however, are located near the boundaries of the airshed where there is an inflow, and the overall model performance is not very much affected by the reduction of the number of air quality monitoring stations.

In the sensitivity case 5-2, the deviation in the model prediction J is caused by perturbations in the meterological input data M and in the surface air quality data A. The relationship between the deviation ΔJ and the perturbations ΔM and ΔA may be expressed to second order as follows:

$$\Delta J = \frac{\partial J}{\partial A}\Delta A + \frac{\partial J}{\partial M}\Delta M + \frac{1}{2}\frac{\partial^2 J}{\partial A^2}(\Delta A)^2 + \frac{1}{2}\frac{\partial^2 J}{\partial M^2}(\Delta M)^2 + \frac{\partial^2 J}{\partial A \partial M}\cdot \Delta A \cdot \Delta M$$

$$+ O(\Delta A^3, \Delta M^3, \Delta A^2 \Delta M, \Delta A \Delta M^2) \quad . \qquad \text{(A-1)}$$

As shown in the general sensitivity measures that the reductions in air quality data and meteorological data were not additive (see, for instance, the dosages for cases 3, 5-1 and 5-2), which suggests that the factors are interrelated and that the coupling between ΔA and ΔM is non-negligible. The importance of the coupled sensitivity coefficient $\partial^2 J/\partial A \partial M$ reflects the coupling of chemical and physical processes in the atmosphere and the importance of including in a mathematical model all atmospheric phenomena without dissociating them.

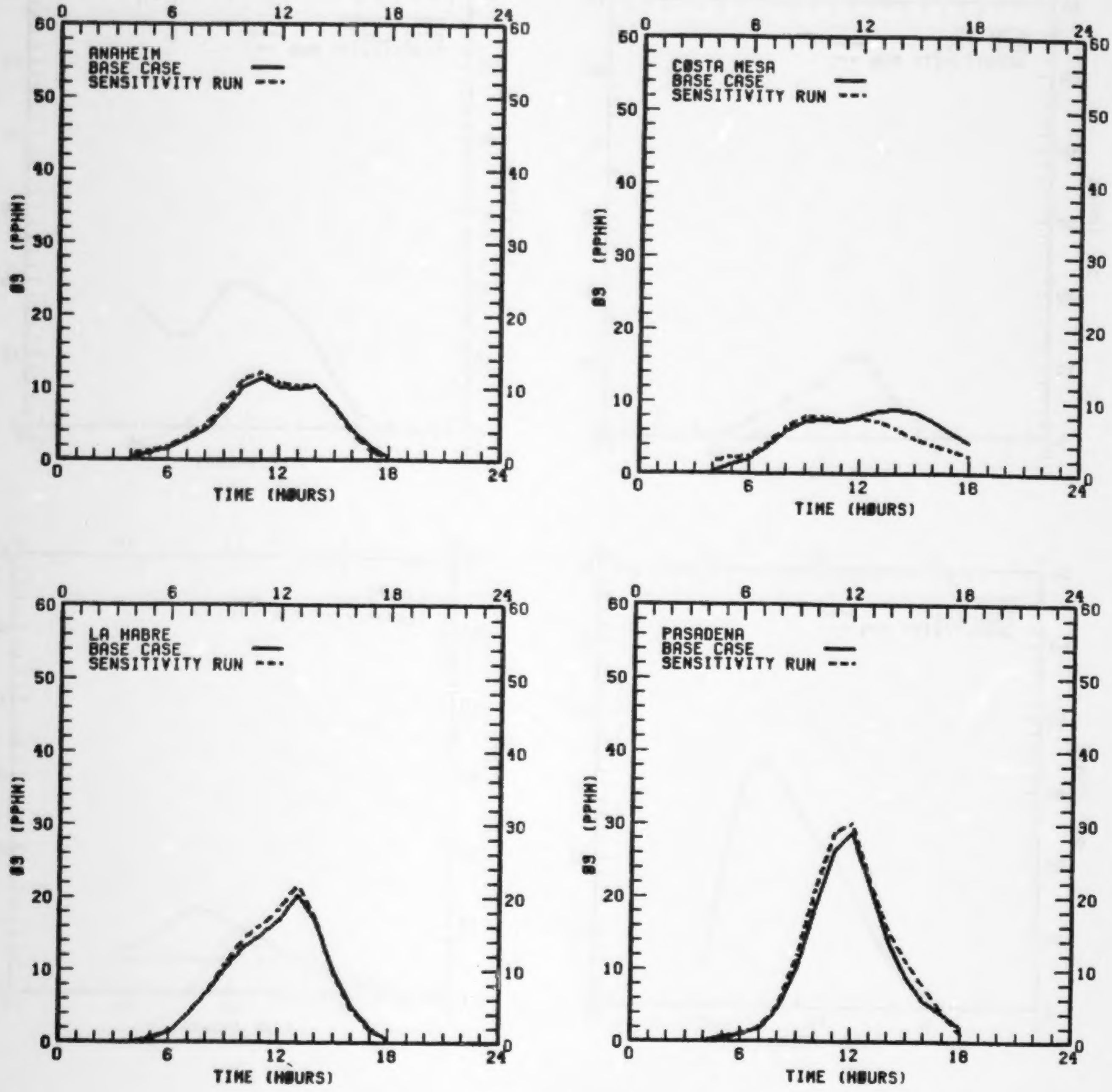

FIGURE A-26. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 5.1

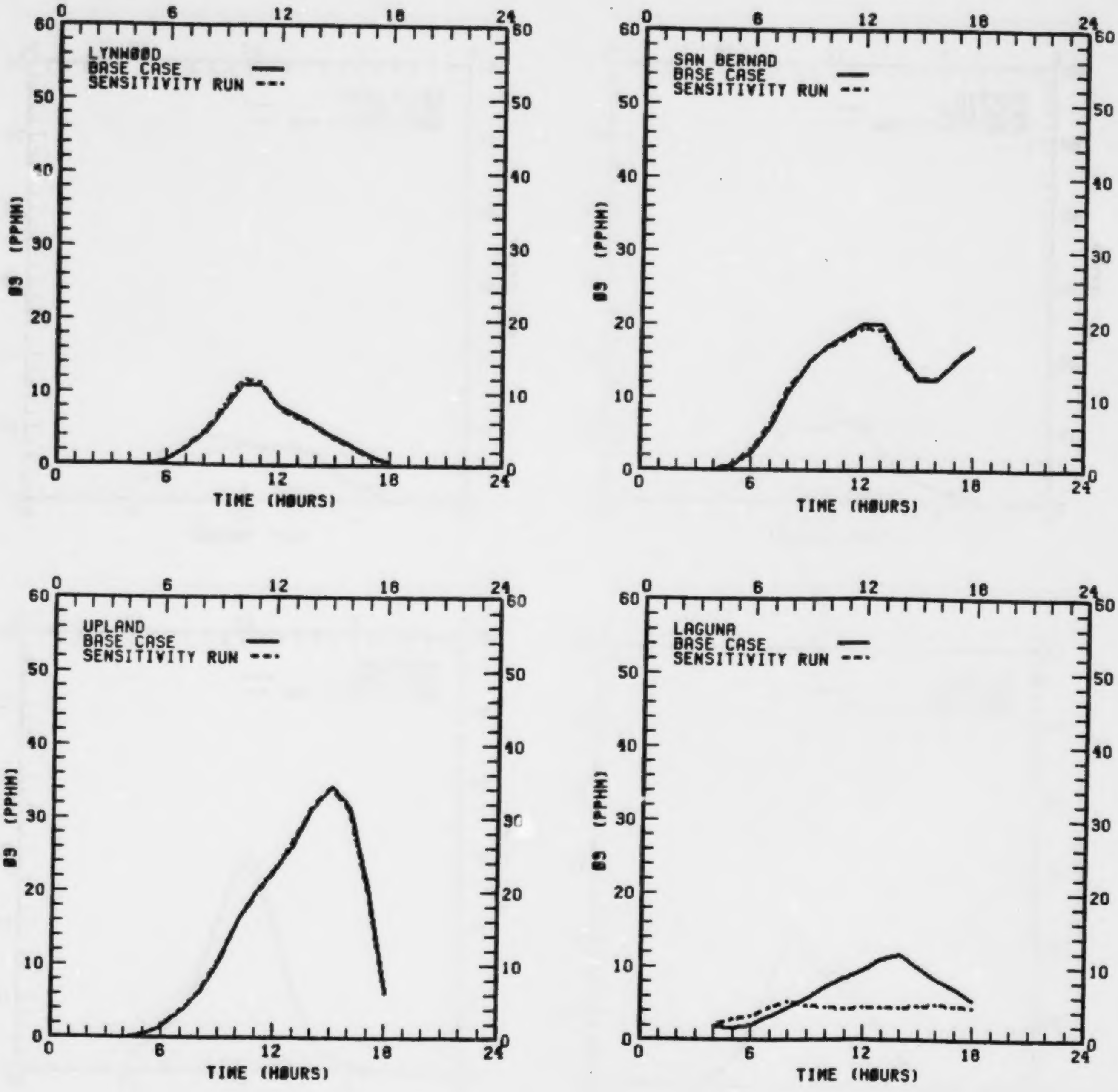

FIGURE A-26 (Concluded)

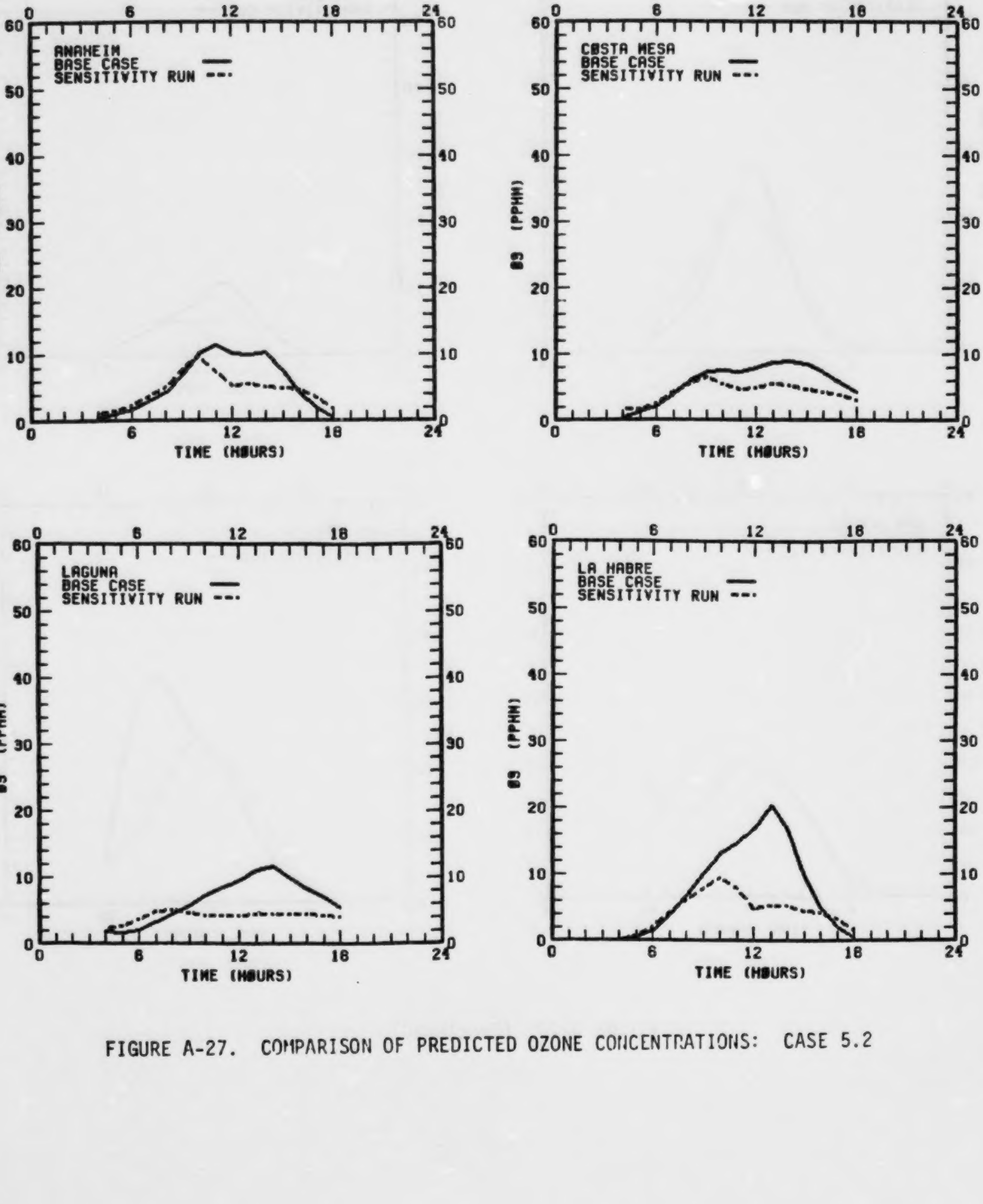

FIGURE A-27. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 5.2

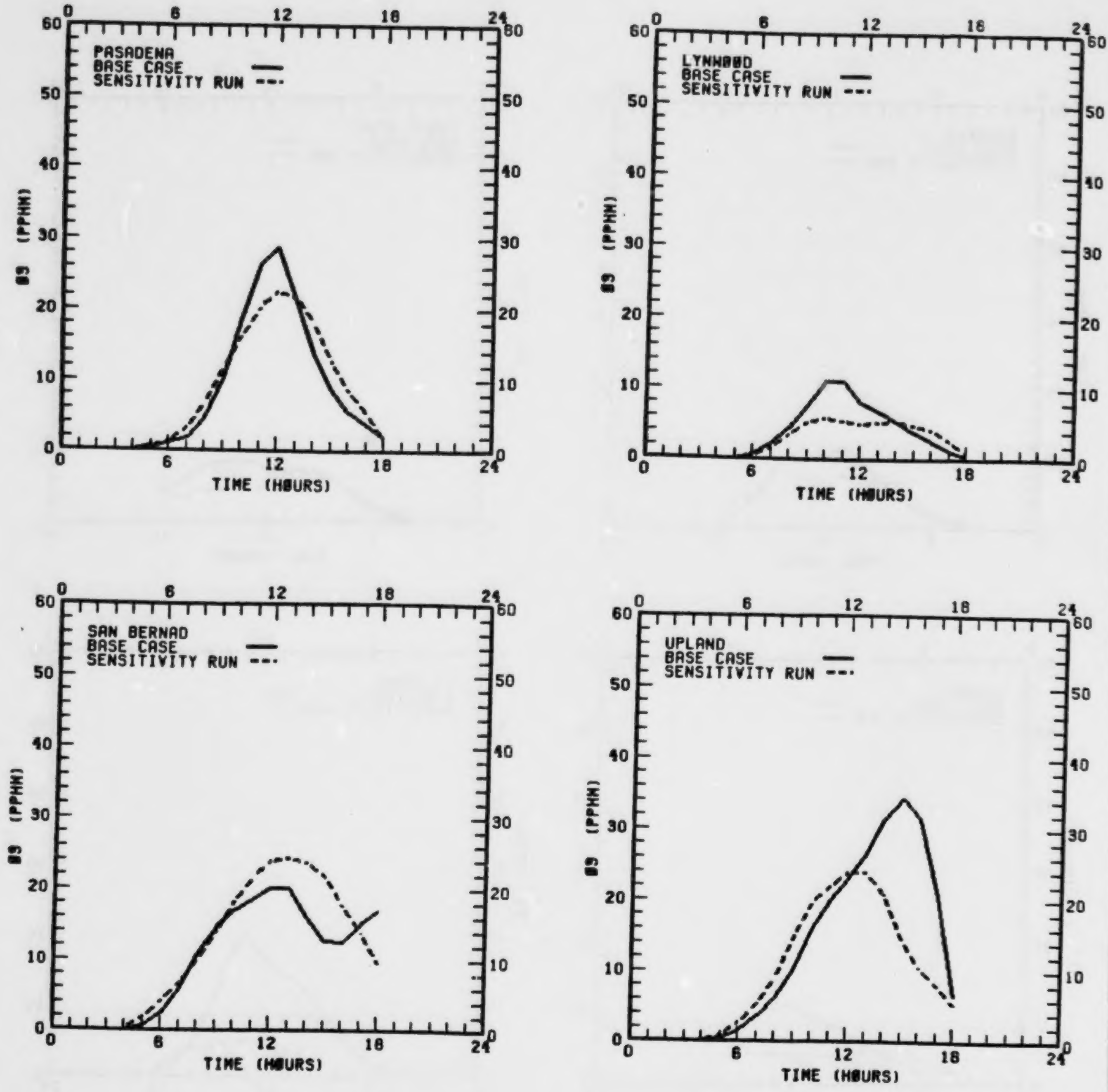

FIGURE A-27 (Concluded)

4) Conclusions

The reduction of the number of air quality monitoring stations does not greatly affect the model predictions. Obviously, the choice of the location of the monitoring stations is important. The locations appear to have been appropriate in these sensitivity studies, since the perturbations are limited to small areas along the airshed boundaries. It should be noted, however, that the Los Angeles basin monitoring network is rather dense, and it is not surprising that the model is relatively insensitive to the intensity of surface air quality data. It would be interesting to determine the minimum set of air quality monitoring stations that could be used without affecting the model predictions notably.

Once the minimum number of air quality stations has been determined, the optimal spatial distribution of these stations should be considered. This optimization problem could be solved once an appropriate performance measure has been determined (e.g., maximum hourly averaged ozone levels, number of days on which air quality standards are exceeded).

Finally, the complexity of atmospheric dynamics appears clearly in these sensitivity studies, where the coupling of meteorological and chemical processes is apparent.

f. Model Sensitivity to Upper Air Quality Data--Simulation of 26 June 1974

In this sensitivity study, the initial concentrations of nitrogen oxides and reactive hydrocarbons in the third layer of the grid model (i.e., above the inversion) were taken to be half their value in the second cell. In the base case, precursor levels were assumed to be representative of "clean air background".

1) General Sensitivity Measures

Some general sensitivity measures of the model to upper air quality data are listed in table A-10; generally higher ozone levels are observed. The largest deviations are obtained for the ozone peak levels (16.2 percent for all stations). The temporal and spatial correlations are relatively high (above 0.94) for all ozone levels. Overall, higher precursor levels above the inversion layer in the morning lead to higher ozone levels, without notably perturbing the spatial and temporal features of the model predictions.

TABLE A-10. GENERAL SENSITIVITY MEASURES--CASE 6

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	$O_3 > 12$ pphm	$O_3 > 20$ pphm	$O_3 > 12$ pphm	$O_3 > 20$ pphm
Signed deviation	0.105	0.110	0.103	0.110
Absolute deviation	0.106	0.110	0.108	0.113
Temporal correlation	0.981	0.983	0.977	0.972
Spatial correlation	0.975	0.959	0.961	0.941

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	1.109	1.122
Peak level (pphm):		
Sensitivity case	39.3	43.6
Base case	35.5	38.9
Corresponding locations:		
Sensitivity case	Upland	33 - 14
Base case	Azusa	33 - 14

12R 3

TABLE A-10 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.162	0.144
Peak time lag (hrs)	0.57	0.13

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
0.4525	14,525	10,000

2) Sensitivity of Model Input Variables to Input Data

In this sensitivity study, the upper level initial conditions have been modified for nitrogen oxides and hydrocarbons. The importance of this initial condition on the system of continuity equations will determine the sensitivity of the model to upper air quality data.

3) Sensitivity of Ozone Levels to Precursor Initial Upper Boundary Conditions

Isopleths of variations in maximum ozone levels are shown in figure A-28. Higher ozone levels on the order of 20 to 40 ppb are observed throughout the basin, except in the southwestern part where lower ozone levels appear. In general, an inflow of precursors from aloft leads to overall higher ozone levels. In the southwestern part of the basin, photochemical smog formation is in its initial stage, since the wind flow is from the southwest. Therefore, an increase of precursor levels may lead to an inhibiting effect of nitric oxide on ozone formation and to lower ozone levels.

Ozone profiles at eight air monitoring stations are shown in figure A-29 for this sensitivity case and the corresponding base case. Higher ozone levels are observed, except at the coastal Laguna station where nitric oxide probably inhibits ozone formation. This effect, however, does not appear at the nearby Costa Mesa station. The deviation in the time of the peak at the inland stations is small, and inland ozone level predictions are perturbed only in magnitude.

4) Conclusions

The upper air initial conditions for nitrogen oxides and hydrocarbons have some effect on the magnitude of the ozone levels but do not perturb the spatial and temporal features of the model. In model applications, the importance of these initial conditions will depend on the meteorological characteristics of the area considered. It is probable that in a well ventilated area the mapping of pollutants above the inversion layer will not be important. It has been shown, however, that under suitable meteorological conditions (such as in the rear part of an anticyclone) pollutants are easily trapped above an inversion layer.

Meteorological considerations and upper air experimental data should provide the information necessary for the definition of the initial upper air pollutant concentrations.

12R 2

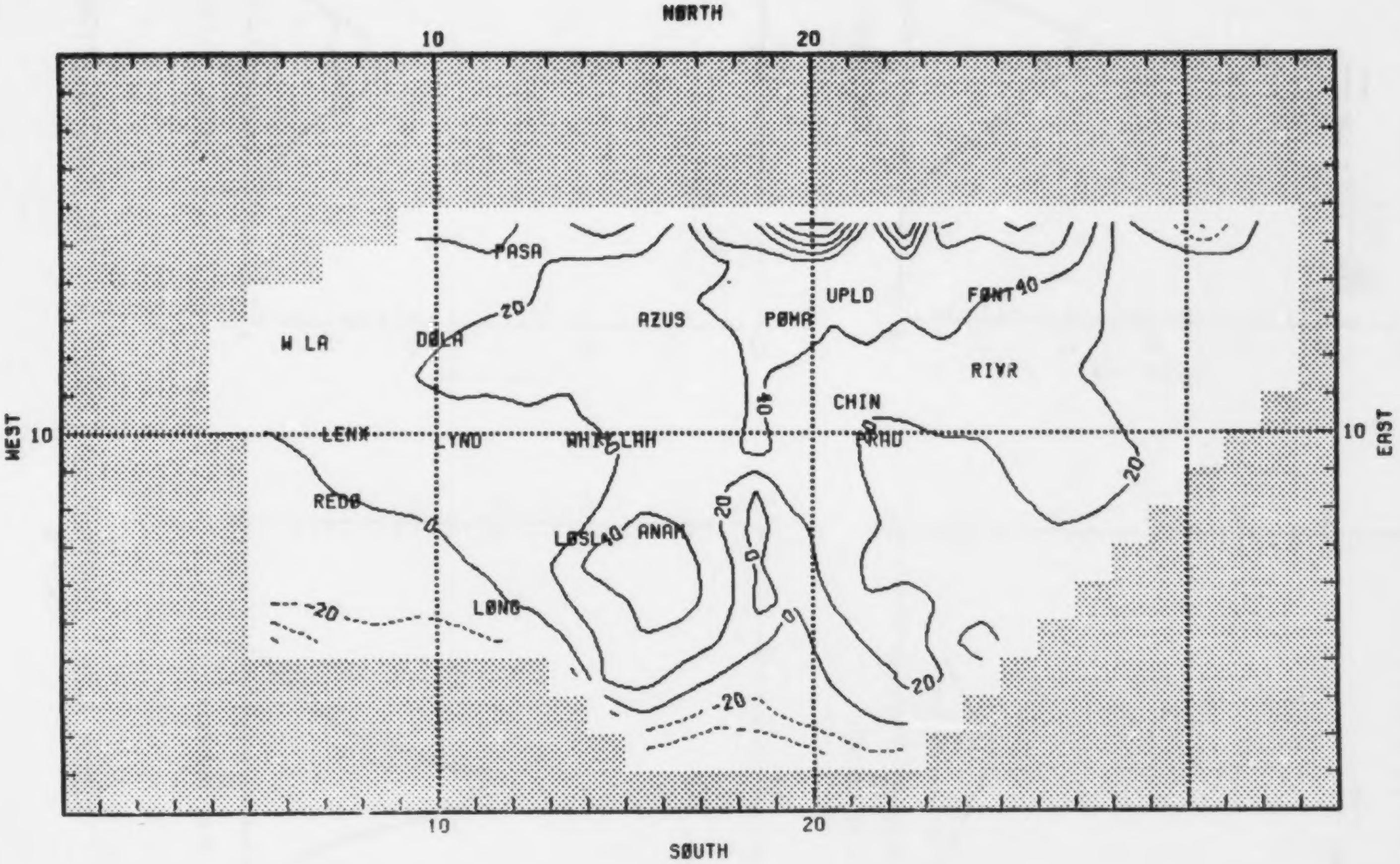
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FIGURE A-28. DEVIATION MAXIMUM OZONE (ppb): CASE 6--BASE CASE BETWEEN THE HOURS OF 3 AND 19 LST

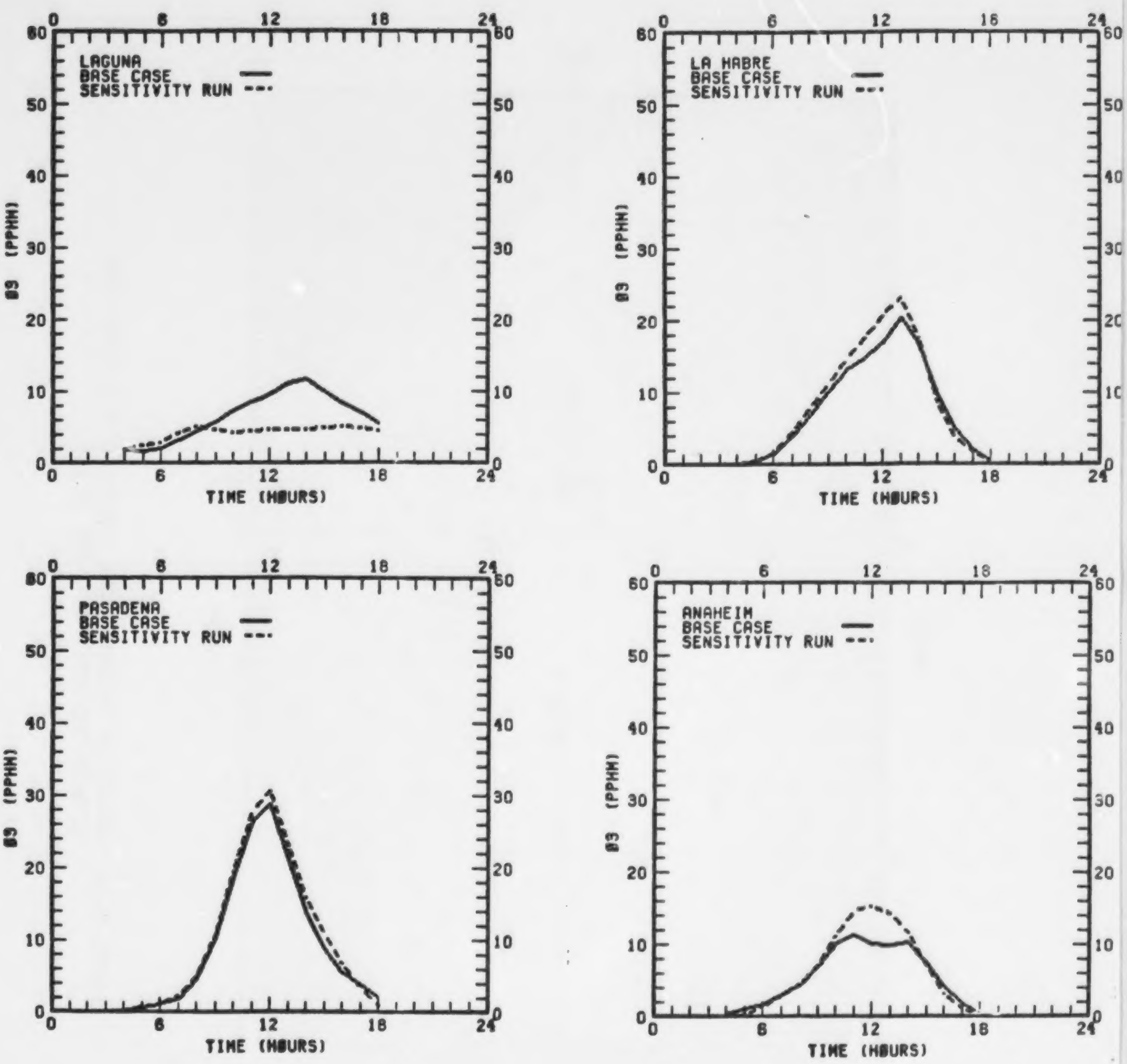

FIGURE A-29. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 6

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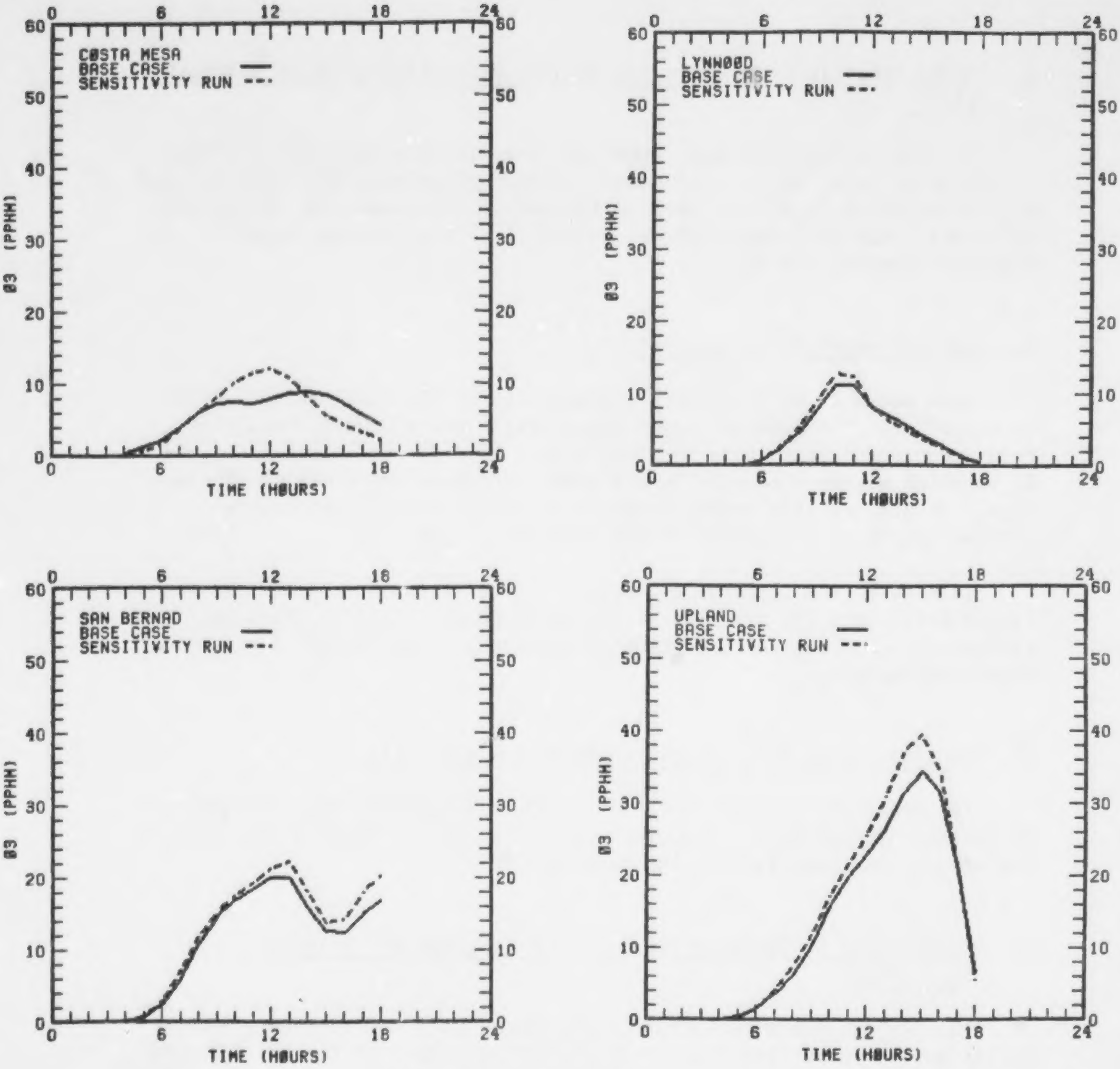

FIGURE A-29 (Concluded)

g. Model Sensitivity to Upper Air Quality Data--Simulation of 4 August 1975

In this sensitivity case, upper air quality data have been modified in the third layer of the grid model. Precursor concentrations of RHC and NO_x in the third layer are lower in the sensitivity case than in the the base case. Boundary conditions at ground level also involve lower precursor concentrations.

1) General Sensitivity Measures

Some measures of the general sensitivity of the model are presented in table A-11. In general, lower ozone levels are observed, resulting from precursor levels above the inversion. This is consistent with case 6, in which higher precursor levels aloft increased photochemical formation. It appears that ozone formation is slightly sensitive to the initial amount of precursors in the third grid layer.

In case 6, the temporal and spatial correlations are relatively high (above 0.95), and the time lag of the ozone peaks is fairly short (an average of 4 minutes for the downwind stations). The dosage is the most sensitive measure.

2) Sensitivity of Model Input Variables to Input Data

The upper air initial conditions have been modified for nitrogen oxides and hydrocarbons. Precursor concentrations in level 3 are lower in the sensitivity case than in the base case.

3) Sensitivity of Ozone Levels to Precursor Upper Air Initial Conditions

The maximum ozone perturbation isopleths are shown in figure A-30. Deviations in ozone levels occur in the northern part of the basin around Pasadena and Pomona. Other areas do not show any major perturbations in ozone-level predictions.

In figure A-31 ozone profiles for this sensitivity case and the base case are shown for six air quality monitoring stations. Slightly lower ozone levels are observed, but the timing and shapes of the ozone profiles are not much perturbed.

TABLE A-11. GENERAL SENSITIVITY MEASURES--CASE 7

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	O_3 > 12 pphm	O_3 > 20 pphm	O_3 > 12 pphm	O_3 > 20 pphm
Signed deviation	-0.073	-0.048	-0.071	-0.053
Absolute deviation	0.073	0.049	0.073	0.057
Temporal correlation	0.980	0.982	0.981	0.950
Spatial correlation	0.953	0.996	0.965	0.970

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	0.927	1.019
Peak level (pphm):		
Sensitivity case	24.4	37.7
Base case	26.3	37.0
Corresponding locations:		
Sensitivity case	Pomona	30 - 16
Base case	Pomona	30 - 16

TABLE A-11 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.0570	0.0694
Peak time lag (hrs)	0.04	0.06

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
-0.504	4,350	8,750

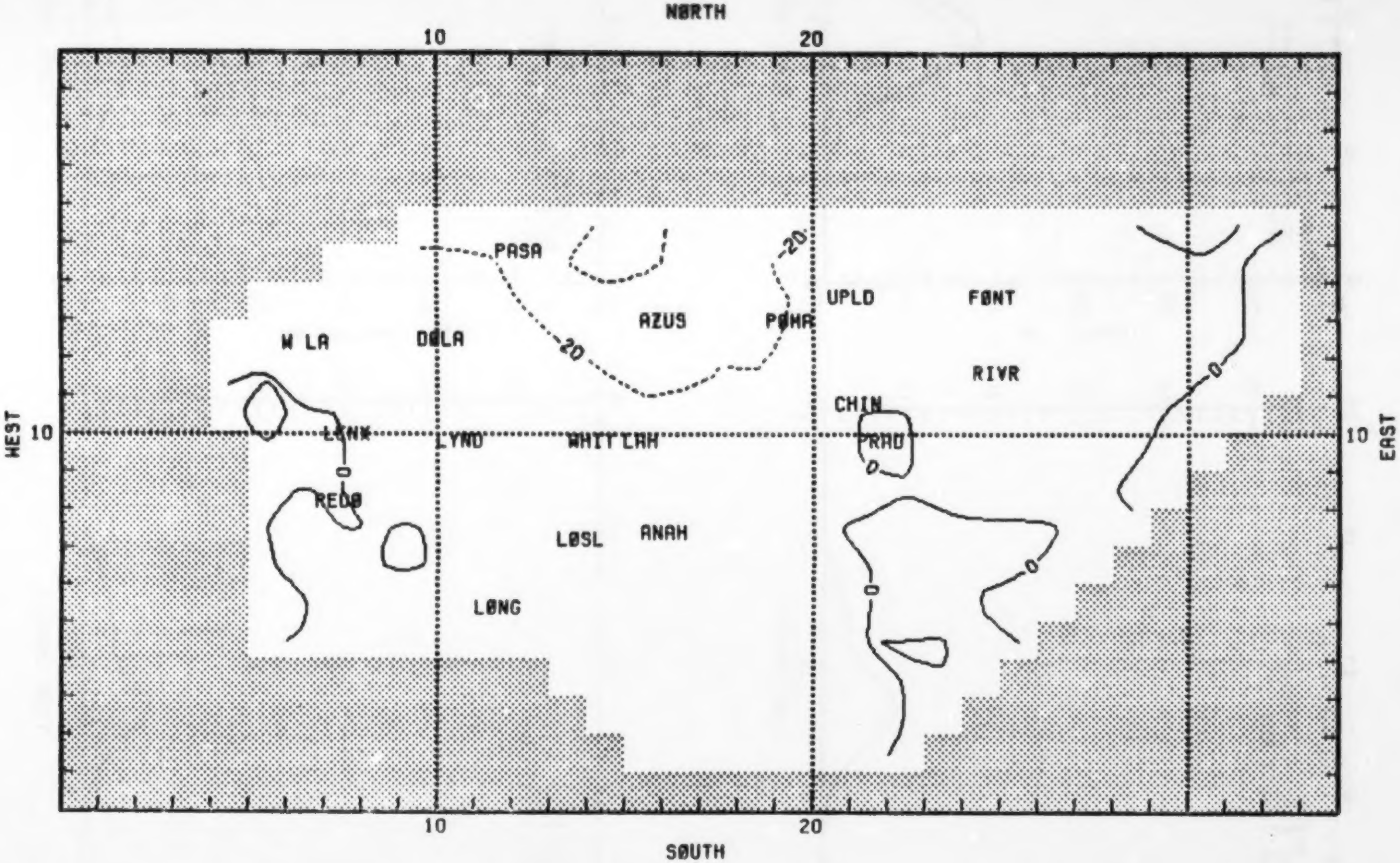
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FIGURE A-30. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 7--BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST

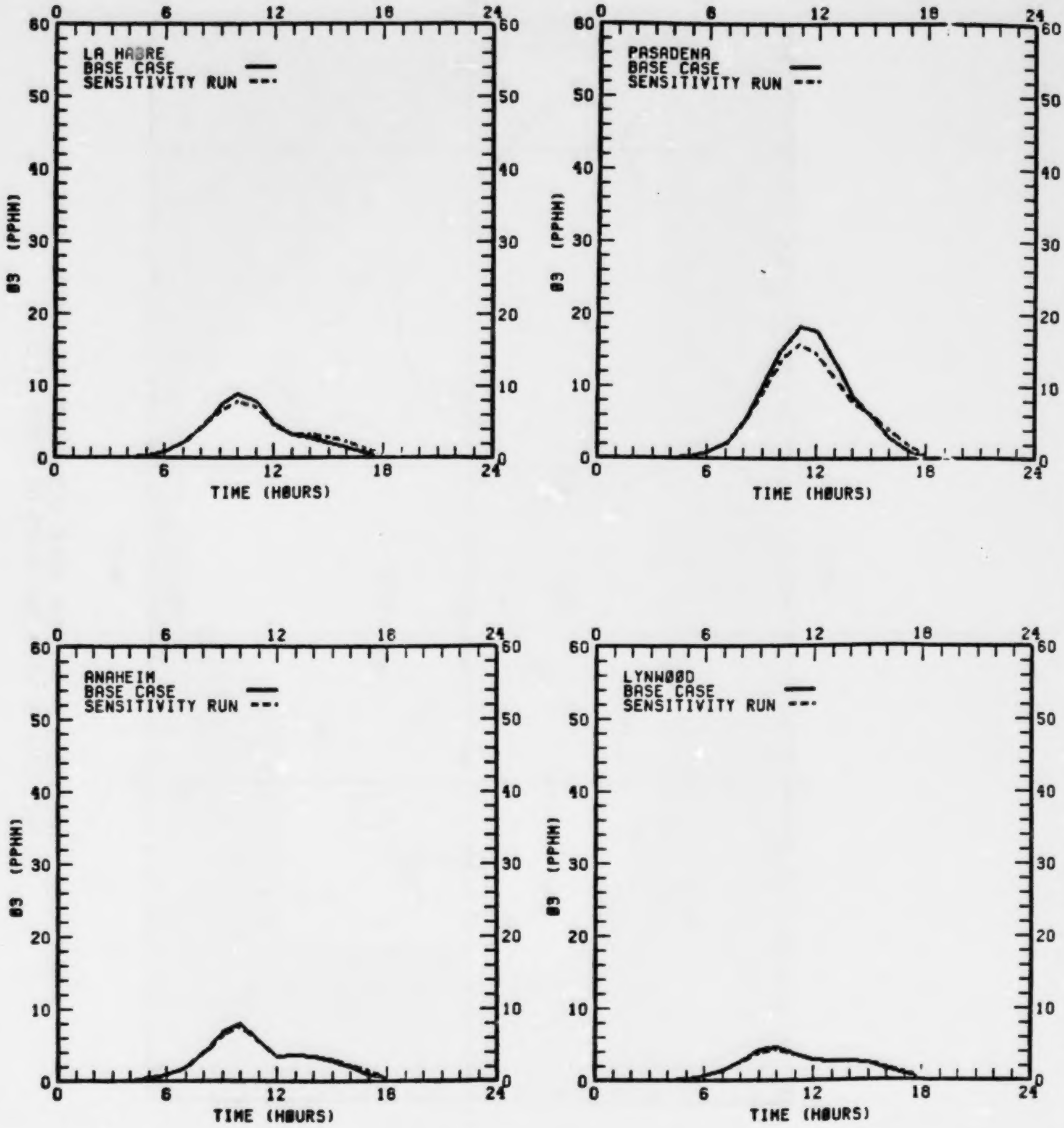

FIGURE A-31. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 7

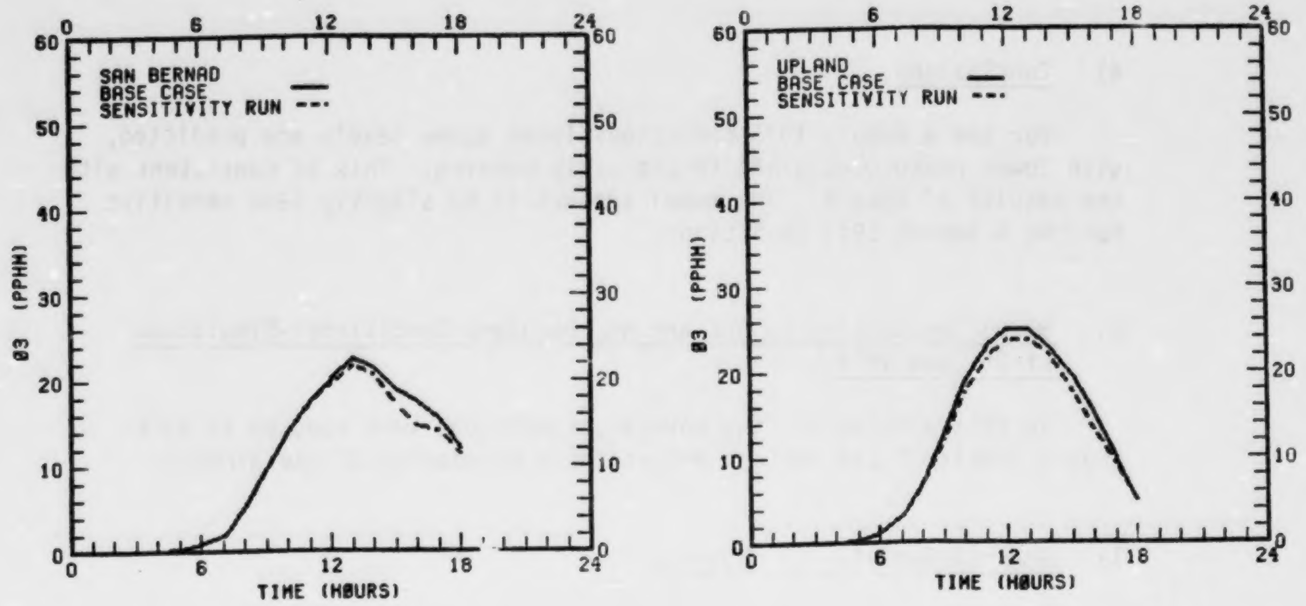

FIGURE A-31 (Concluded)

4) Conclusions

For the 4 August 1975 conditions lower ozone levels are predicted, with lower precursors aloft in the early morning. This is consistent with the results of case 6. The model appears to be slightly less sensitive for the 4 August 1975 conditions.

h. Model Sensitivity to RHC and NO_x Boundary Conditions--Simulation of 26 June 1974

In this simulation, the boundary conditions were reduced to background levels at the western and southern boundaries of the airshed.

1) General Sensitivity Measures

Some measures of the general sensitivity of the model are presented in table A-12. Lower ozone levels are predicted when boundary concentrations of nitrogen oxides and RHC are lower. This is consistent with case 6, where higher precursor levels at the upper boundary induced higher ozone levels. The temporal correlation is high (above 0.9), and the overall ozone maximum occurs at the same location (Azusa, or grid [33-14]); however, the spatial correlation is rather low (about 0.6) for ozone levels above 20 pphm.

2) Sensitivity of Model Input Variables to Input Data

The nitrogen oxides concentrations have been reduced at the western and southern boundaries. The wind flow is westerly, and this boundary condition is important, since it is given by the following equation:

$$\underline{v} \, \nabla \, C_i^E - \nabla \, \underline{\underline{K}} \, \nabla \, C_i^E = \underline{V} \, \nabla \, C_i^I - \nabla \, \underline{\underline{K}} \, \nabla \, C_i^I \quad . \qquad \text{(A-2)}$$

where V is the wind vector, K the eddy diffusivity tensor, and C_i^E and C_i^I the concentrations of species i outside and inside the domain, respectively. In the case of an outflow (e.g., at the northern and eastern boundaries) the boundary condition does not depend on the species concentrations outside of the domain and is simply given by the following equation:

TABLE A-12. GENERAL SENSITIVITY MEASURES--CASE 8

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	O_3 > 12 pphm	O_3 > 20 pphm	O_3 > 12 pphm	O_3 > 20 pphm
Signed deviation	-0.141	-0.177	-0.130	-0.165
Absolute deviation	0.145	0.181	0.139	0.169
Temporal correlation	0.914	0.933	0.925	0.928
Spatial correlation	0.927	0.613	0.896	0.794

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	0.804	1.002
Peak level (pphm):		
Sensitivity case	28.5	38.9
Base case	35.5	38.9
Corresponding locations:		
Sensitivity case	Azusa	33 - 14
Base case	Azusa	33 - 14

TABLE A-12 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.188	0.187
Peak time lag (hrs)	0.870	0.750

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
-0.38	6,200	10,000

$$\nabla \underline{\underline{K}} \nabla C_i^I = o \quad . \qquad \text{(A-3)}$$

Where there is inflow, the boundary condition affects the dynamic behavior of the continuity equations. The sensitivity results will provide some estimate of the importance of the boundary condition on the model.

3) Sensitivity of Ozone Levels to Nitrogen Oxides Boundary Conditions

Isopleths of maximum ozone deviation are shown in figure A-32. The largest ozone deviations occur in the northern part of the basin, from Pasadena to Riverside. As mentioned in the discussion of the general sensitivity results, lower nitrogen oxides boundary concentrations result in lower ozone levels. This appears clearly in figure A-33, where ozone profiles for the base case and the sensitivity case are shown at six air monitoring stations.

The effect of the western boundary condition increases as the chemical reactions proceed in time during the eastward transport of the polluted air masses, then decreases farther downwind as new injections of nitrogen oxides from emission sources modify the system's kinetics (compare, for instance, the ozone profiles at Anaheim, Upland, and San Bernardino). The boundary condition of the urban airshed model can be interpreted as the initial condition of a Lagrangian trajectory model. The effect of the initial conditions is small when little ozone has been formed (e.g., at Anaheim) and increases when ozone builds up (e.g., at Pasadena or Upland).

Finally, when more emissions are introduced into the air mass, the initial conditions are "forgotten," and the perturbation in the ozone level decreases again.

4) Conclusions

This sensitivity study shows that the chemical kinetic behavior of the urban airshed is sensitive to the upwind boundary condition (for nitrogen oxides). This condition should, therefore, be presented appropriately. In this case, lower nitrogen oxides concentrations at the upwind boundary induced lower ozone levels downwind; this effect depends on the relative concentrations of atmospheric pollutants however (nitrogen oxides, hydrocarbons, ozone). The opposite effect could be obtained under different conditions (e.g., with a different hydrocarbon/nitrogen oxide ratio), and it cannot be predicted *a priori*.

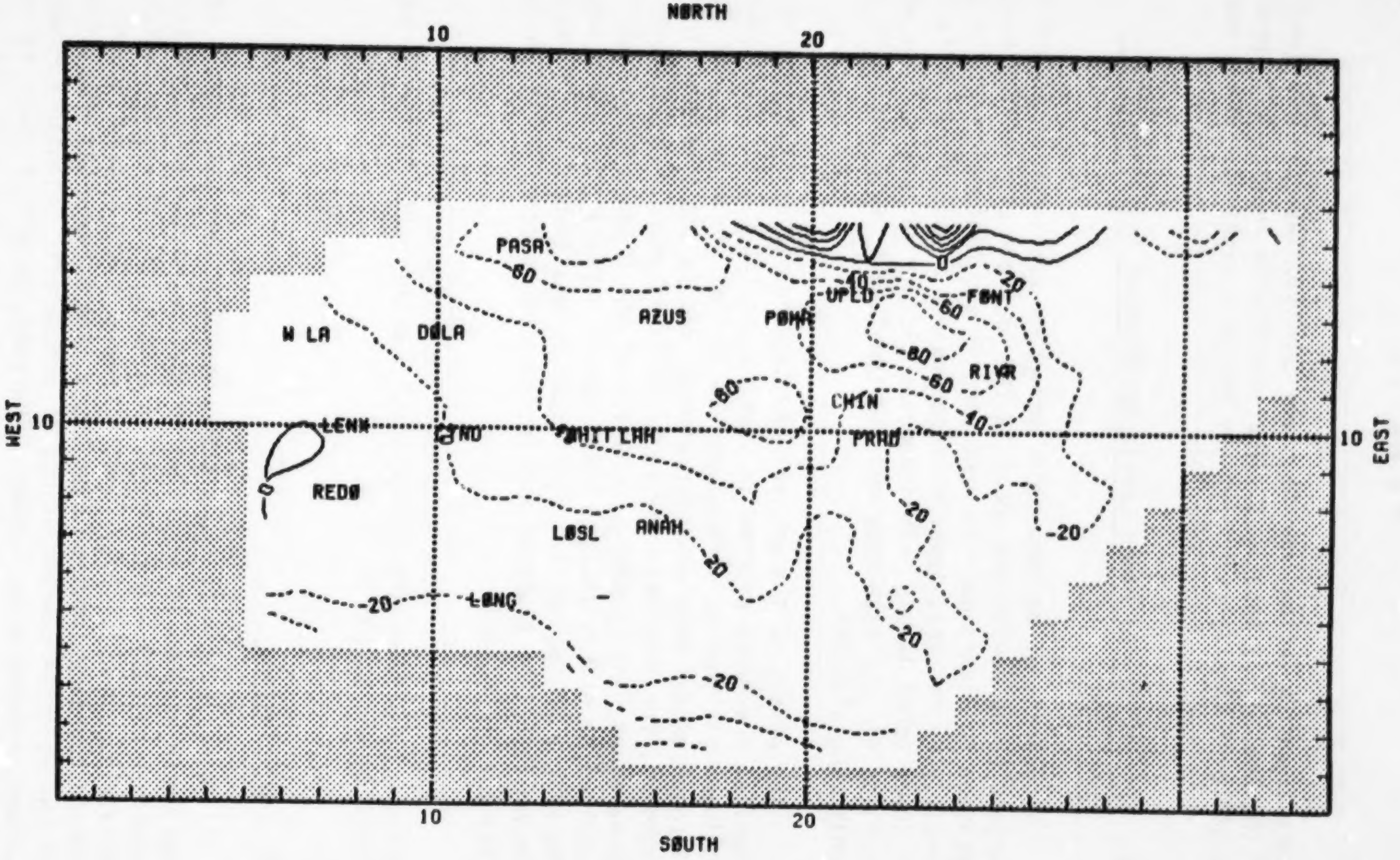
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FIGURE A-32. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 8--BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST

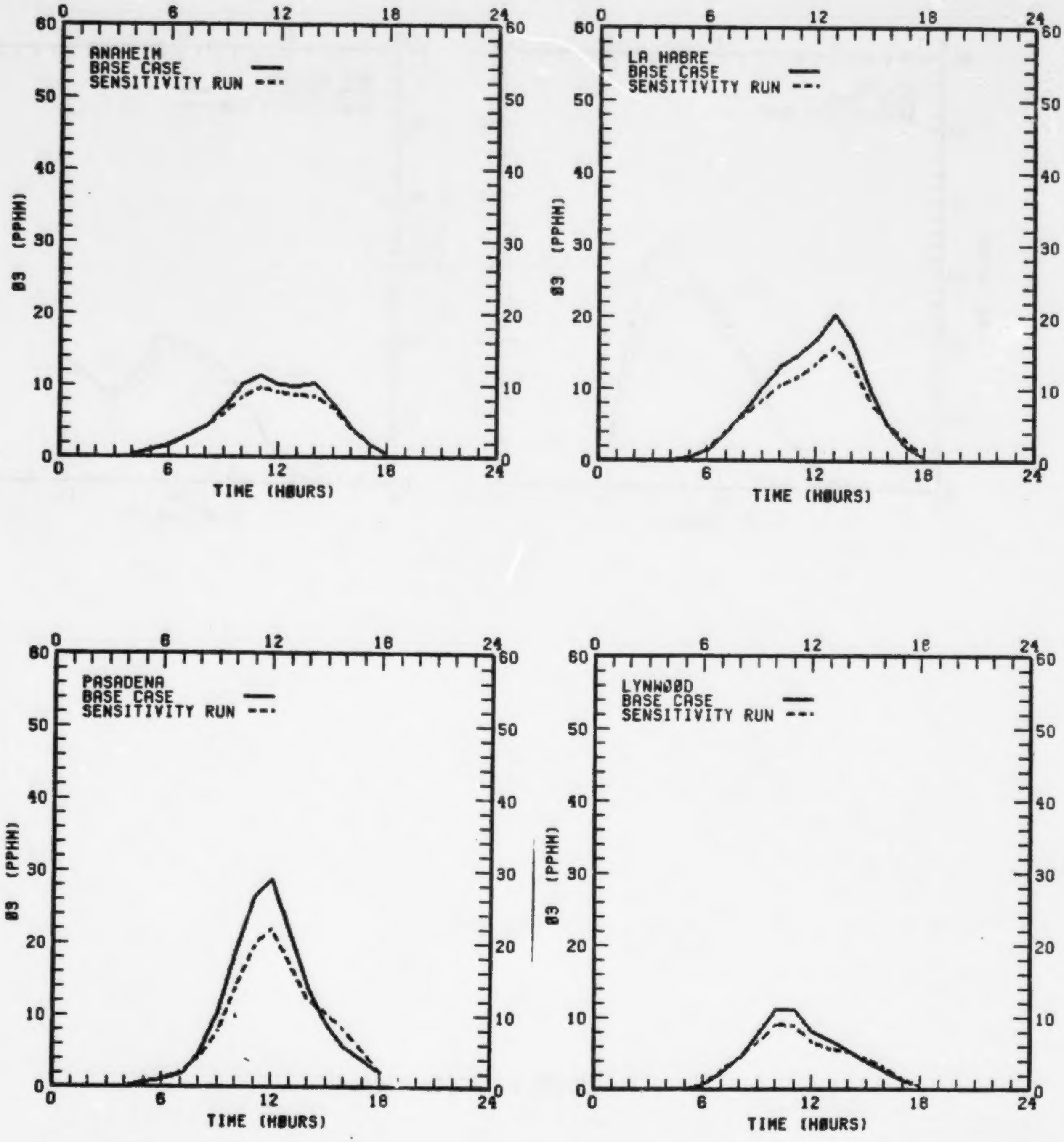


FIGURE A-33. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 8

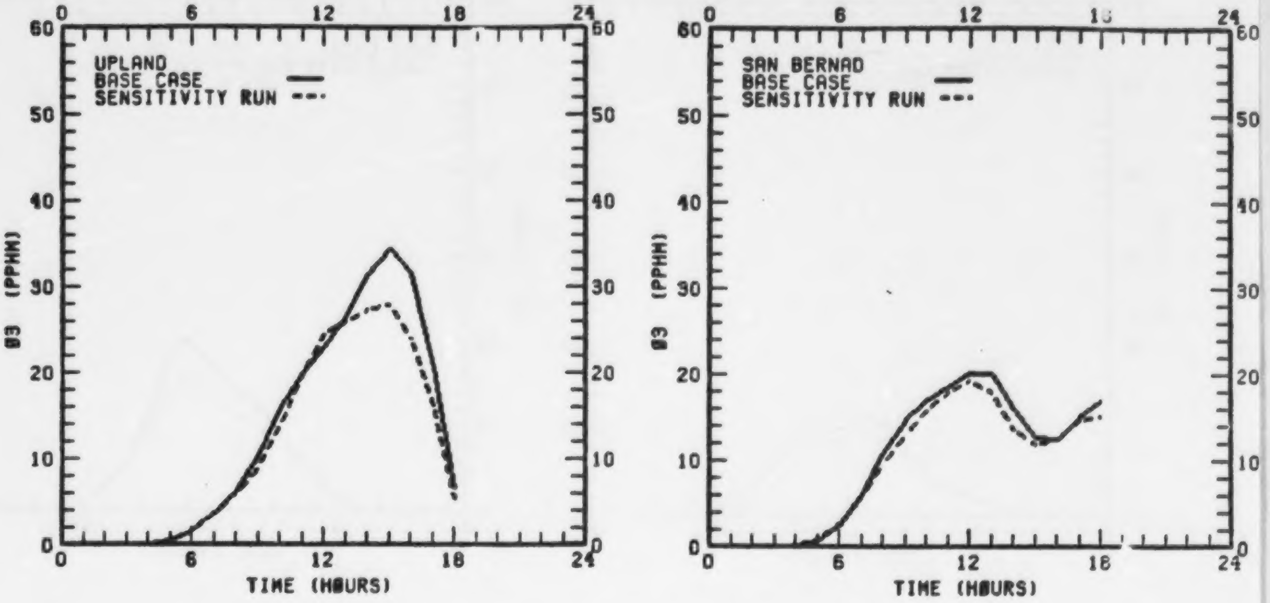


FIGURE A-33 (Concluded)

i. Model Sensitivity to Hydrocarbon Initial Concentrations--Simulation of 26 June 1974

In this sensitivity study, non-methane hydrocarbon initial concentrations were determined from nitrogen oxides initial concentrations according to the relationship $[NMHC]/[NO_x] = 7$. In the base case, nonmethane hydrocarbon initial concentrations were computed from total hydrocarbon concentrations, according to the following formula $[NMHC] = 0.7 ([THC] - 1.3)$, which was obtained from atmospheric data by regression. The initial concentrations of nitrogen oxides are also slightly different. Initial concentrations of nonmethane hydrocarbons and nitrogen oxides are shown in figure A-34.

1) General Sensitivity Measures

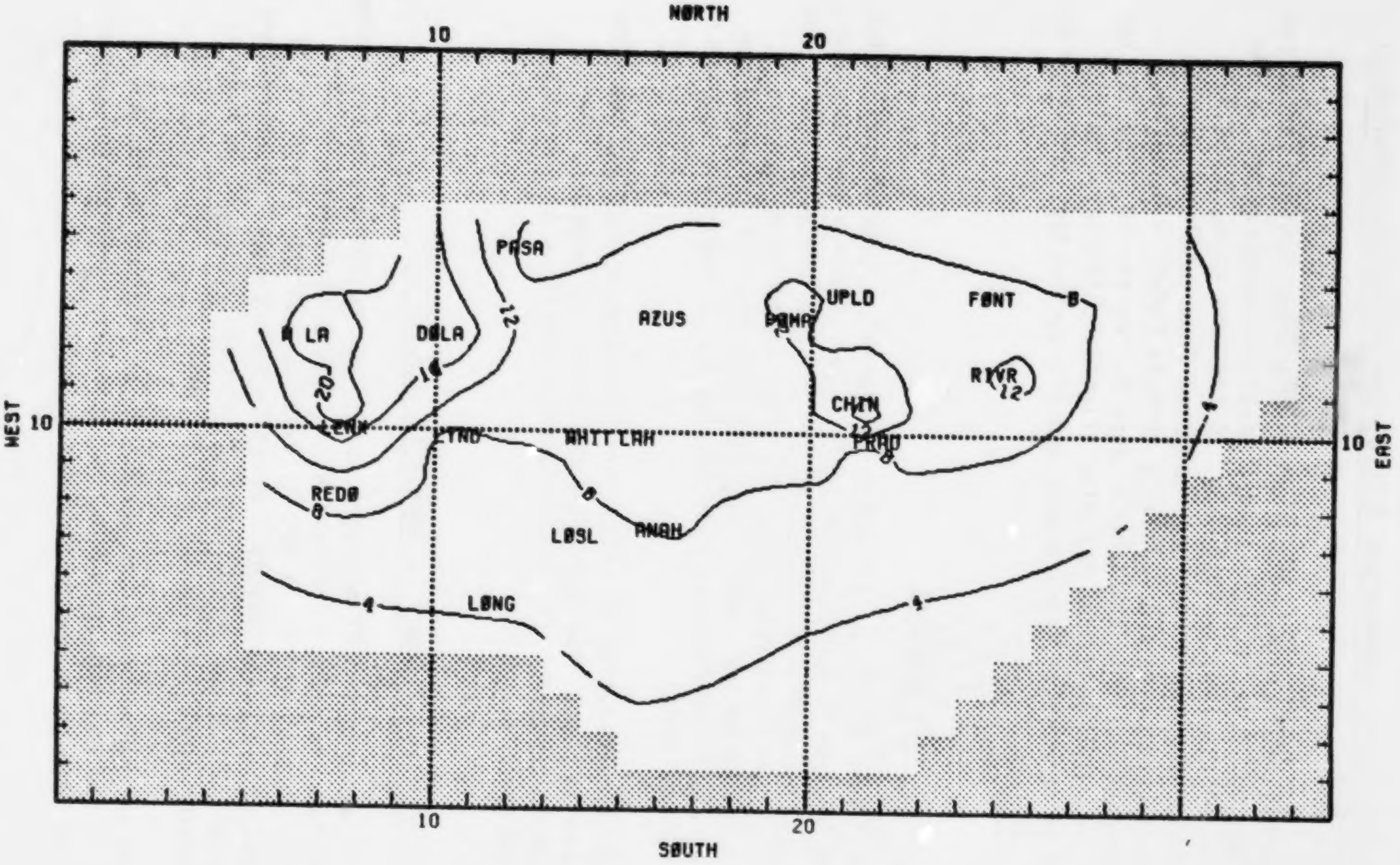
The overall sensitivity of the model to the definition of hydrocarbon initial concentrations is presented in table A-13. Lower ozone levels are obtained with the relationship $[NMHC]/[NO_x] = 7$. The deviation due to the change in initial concentrations is on the order of 30 to 40 percent. This is a large perturbation, and it suggests that the definition of the initial concentrations of reactive hydrocarbons is an important component of the urban airshed model.

The temporal correlation is relatively high (above 0.8) and the time lag is less than an hour. The spatial correlation is, however, low for ozone levels above 20 pphm. The dosage is more sensitive to the perturbation than the other measures.

2) Sensitivity of Model Input Variables to Input Data

Initial concentrations of nitrogen oxides and nonmethane hydrocarbons have been modified, as shown in figure A-34. The perturbation in the nitrogen oxides concentrations is not as important as the change in the reactive hydrocarbon concentrations. Reactive hydrocarbon concentrations are on the order of 0.4 ppm in the sensitivity case; they are as high as 1.8 ppm at Fontana and Riverside in the base case.

According to the relative concentrations of nitrogen oxides and hydrocarbons in the Los Angeles basin, an increase in hydrocarbon concentrations should lead to an increase in ozone levels.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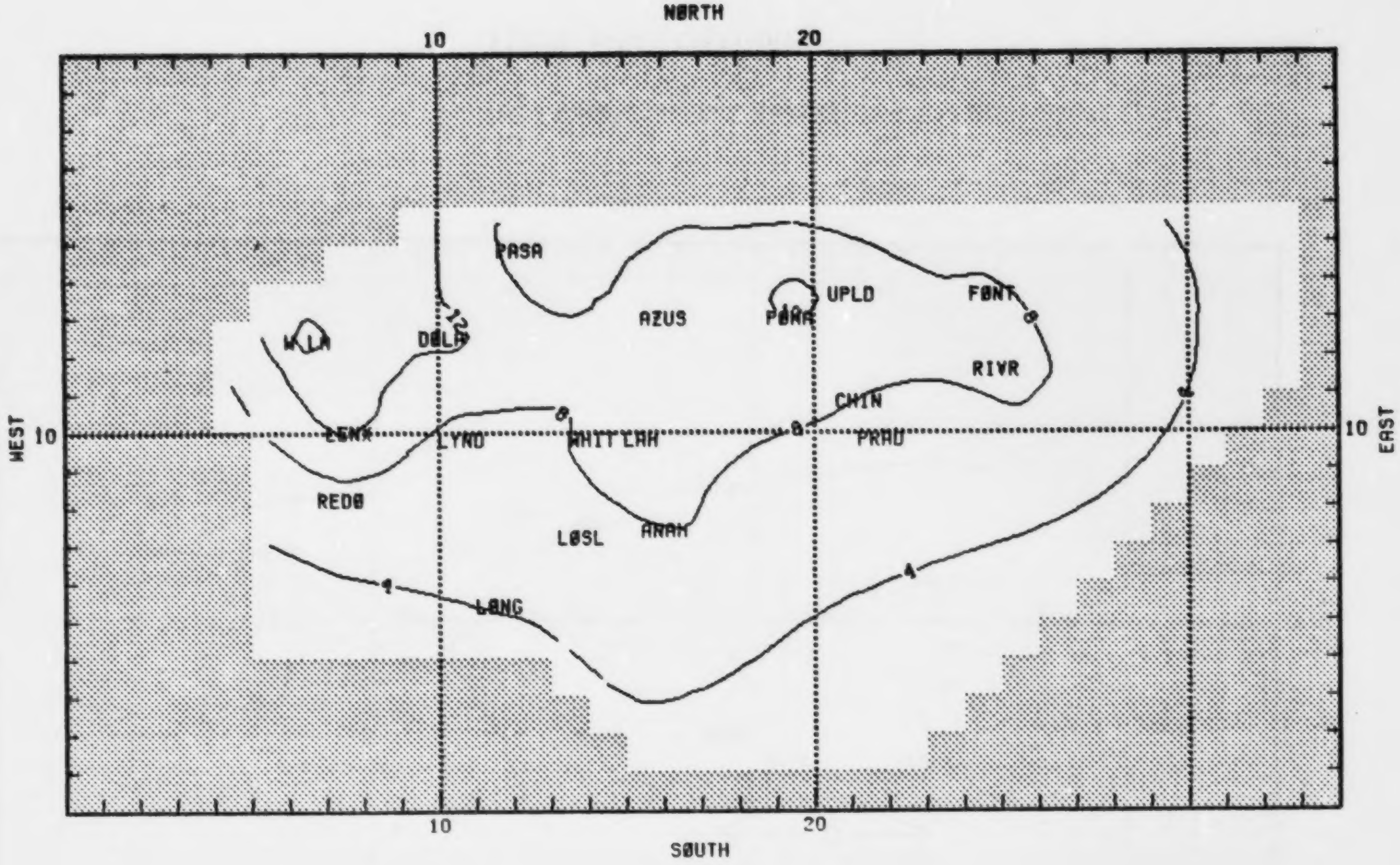
(a) Base Case NO_x (pphm)

FIGURE A-34. INITIAL CONDITIONS FOR 26 JUNE 1974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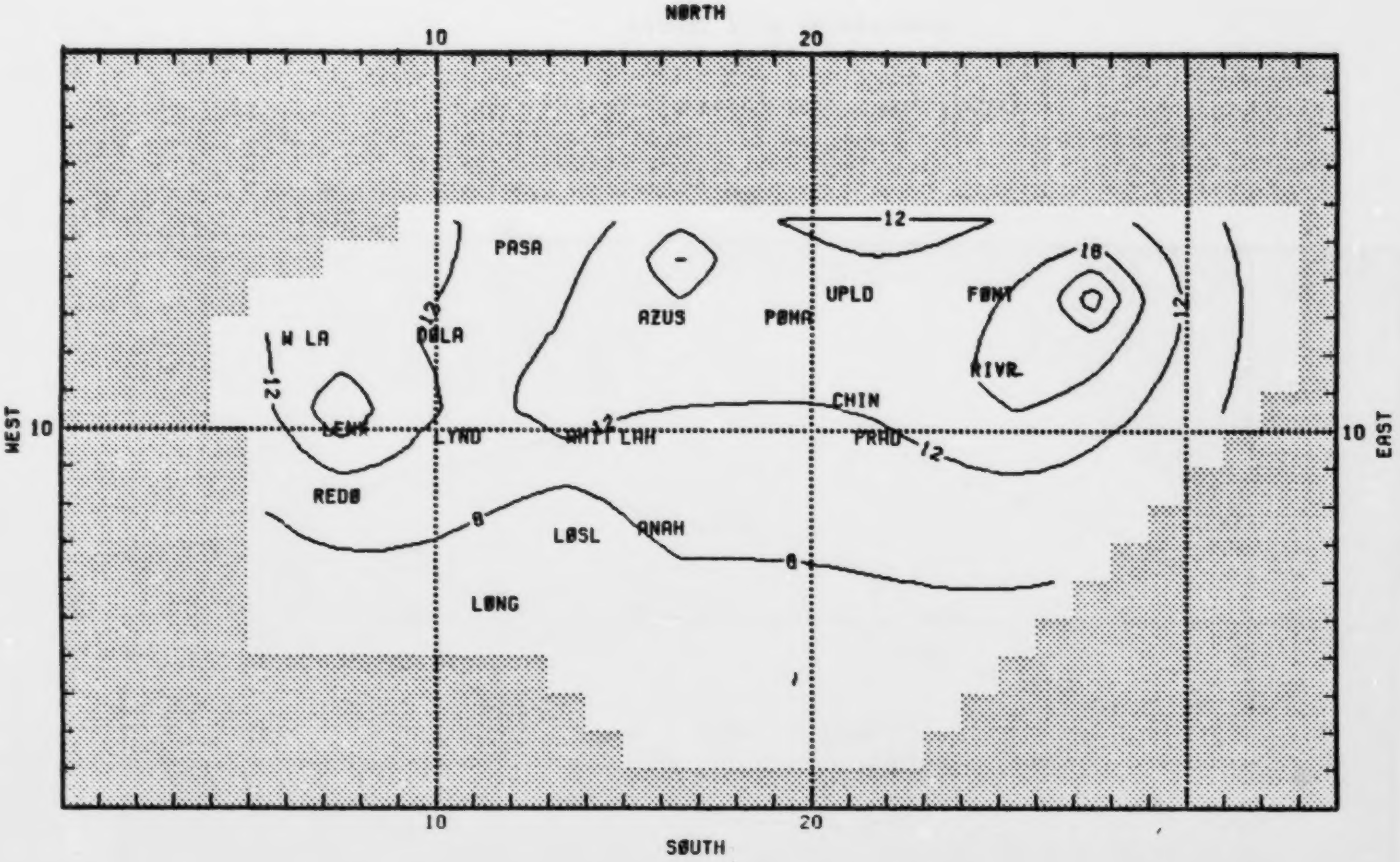
(b) Sensitivity Case 9 NO_x (pphm)

FIGURE A-34 (Continued)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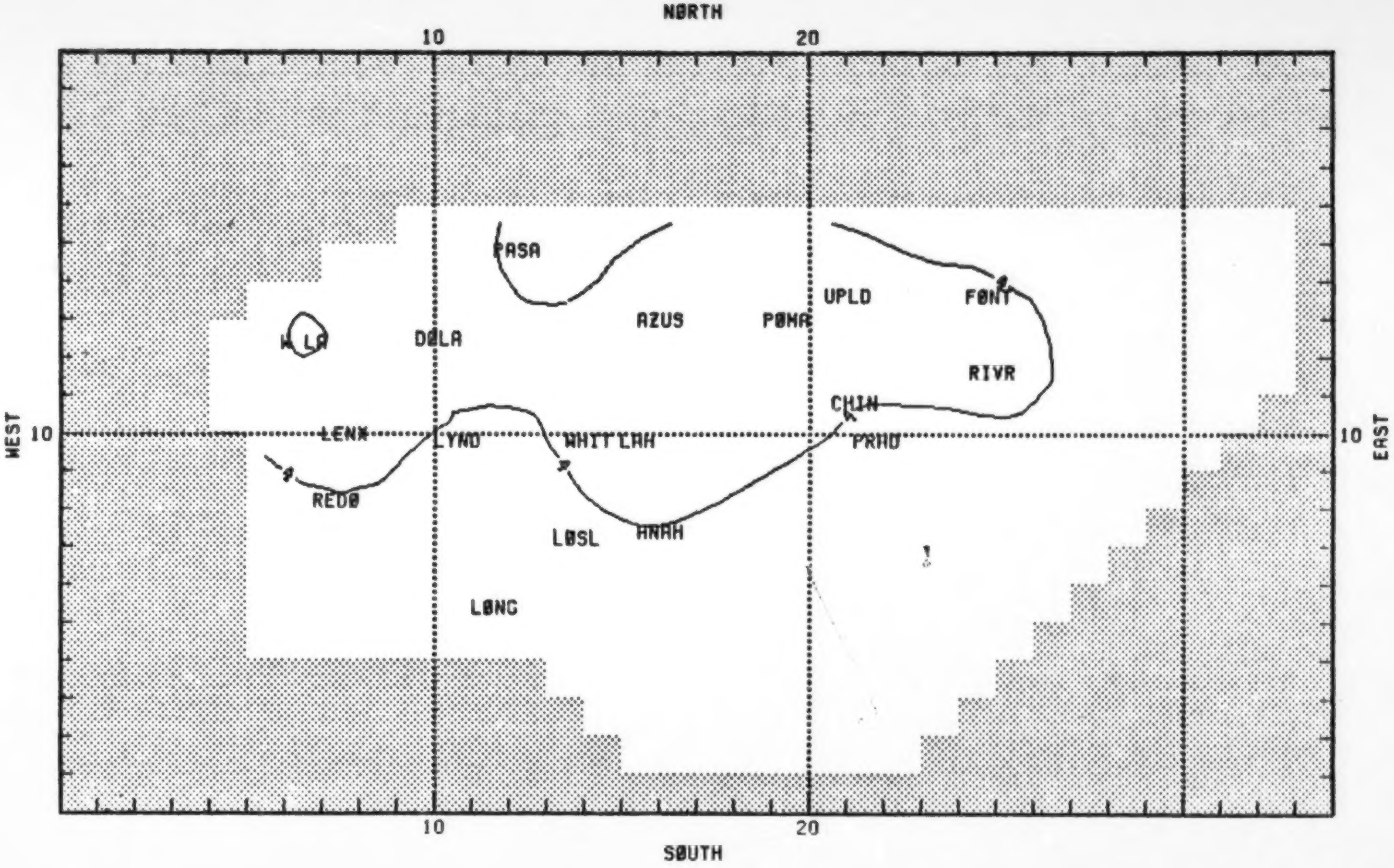
(c) Base Case RHC (pptm)

FIGURE A-34 (Continued)



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(d) Sensitivity Case 9 RHC (pptm)

FIGURE A-34 (Concluded)

TABLE A-13. GENERAL SENSITIVITY MEASURES--CASE 9

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	$O_3 > 12$ pphm	$O_3 > 20$ pphm	$O_3 > 12$ pphm	$O_3 > 20$ pphm
Signed deviation	-0.344	-0.384	-0.317	-0.357
Absolute deviation	0.344	0.384	0.318	0.357
Temporal correlation	0.869	0.984	0.807	0.893
Spatial correlation	0.800	0.433	0.800	0.735

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	0.632	0.832
Peak level (pphm):		
Sensitivity case	22.4	32.4
Base case	35.5	38.9
Corresponding locations:		
Sensitivity case	Upland	33 - 14
Base case	Azusa	33 - 14

TABLE A-13 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.320	0.354
Peak time lag (hrs)	0.96	0.56

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
-0.7575	2,425	10,000

3) Sensitivity of Ozone Levels to Hydrocarbon Initial Concentrations

Isopleths of deviations in maximum ozone levels are shown in figure A-35. Lower ozone levels are observed throughout the basin. The largest deviations from the base case occur in the northern central part of the basin around Pasadena, Azusa, and Pomona, where air pollution is the most important. This appears also in figure A-36, which presents ozone profiles at six air quality monitoring stations for this sensitivity case and for the base case. Ozone peak levels are lower at all stations, but the shape of the peak is usually conserved. The ozone profile at Laguna differs, however, since the ozone peak is reduced at 0800 L.S.T. in the sensitivity case and at 1400 L.S.T. in the base case. The perturbations in the shape of the ozone peaks are larger at the coastal stations and this appears also in the averaged peak time lag (table A-13), which is shorter for downwind stations.

4) Conclusions

Ozone levels are very sensitive to initial concentrations of precursors and are determined by more than pollutant emissions during the simulation day. Thus, the specification of the initial conditions of the species continuity equations is an important component of the urban airshed model.

Atmospheric measurements of reactive hydrocarbons are usually not very accurate, since they are often observed by subtracting methane concentration from total hydrocarbon concentration--that is, by the difference of two close numbers. More reliable measurements may be obtained by gas chromatography, but these are not always available. Consequently, hydrocarbon initial concentrations are usually defined by means of a formula relating reactive hydrocarbon concentrations to some other species concentration that is easily measured (nitrogen oxides, total hydrocarbons).

It appears from this sensitivity study that the choice of this relationship for the estimation of initial reactive hydrocarbon concentrations is a major input of the urban airshed model and that it should be selected carefully.

j. Model Sensitivity to Hydrocarbon Initial Concentrations--Simulation of 4 August 1975

As in case 9, nonmethane hydrocarbon initial concentrations were determined from nitrogen oxides initial concentrations according to the

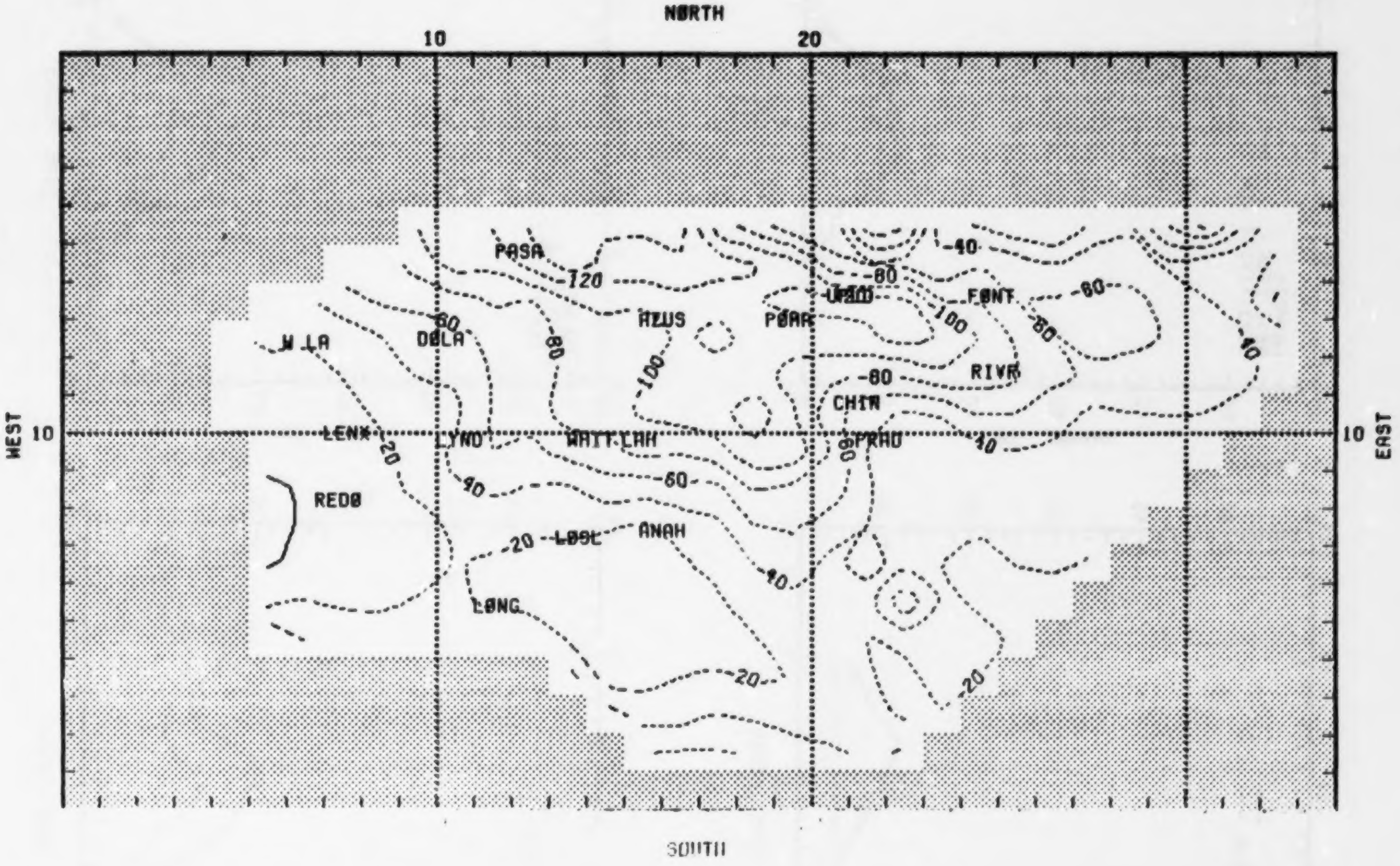
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FIGURE A-35. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 9--BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST

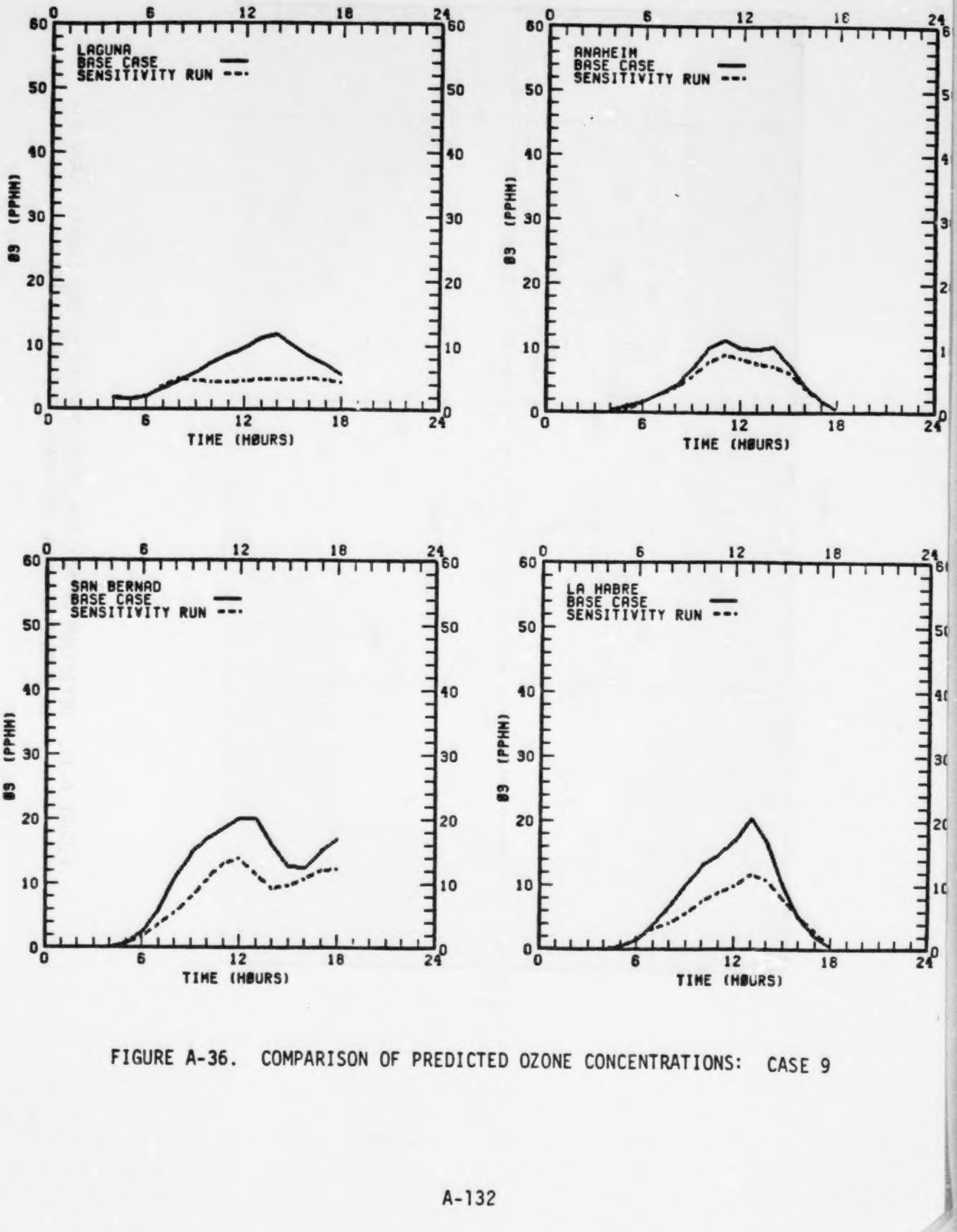


FIGURE A-36. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 9

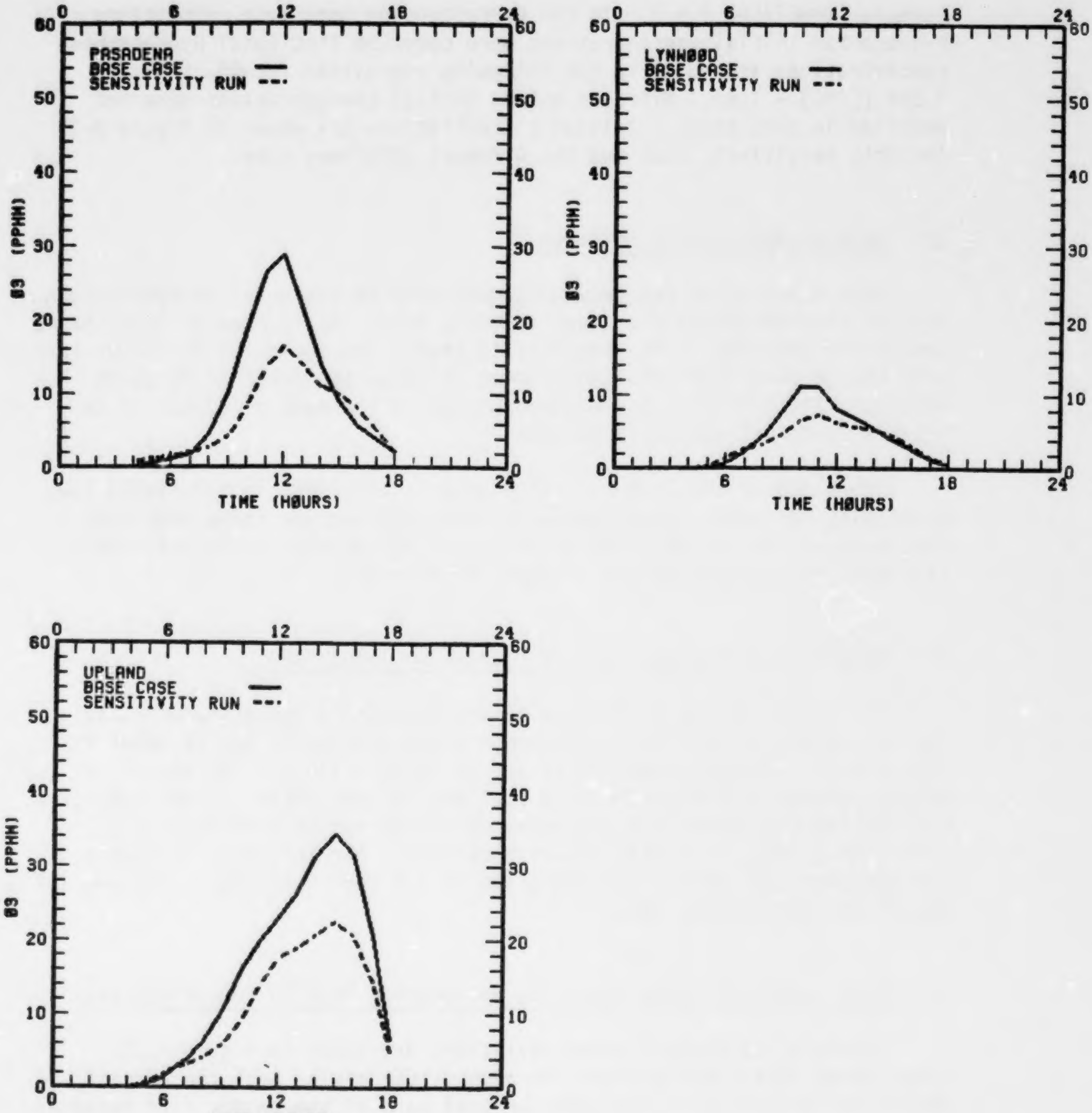


FIGURE A-36 (Concluded)

formula $[NMHC]/[NO_x] = 7$. In the corresponding base case, nonmethane hydrocarbon initial concentrations were computed from total hydrocarbon concentrations according to the following regression formula $[NMHC] = 1.034 ([THC] - 1.4)$. Nitrogen oxides initial concentrations were not modified in this study. Initial concentrations are shown in figure A-37 for this sensitivity case and the 4 August 1975 base case.

1) General Sensitivity Measures

Some measures of the general sensitivity of the model to hydrocarbon initial concentrations are shown in table A-14. As in case 9, lower ozone levels are obtained in the sensitivity case. The deviation is larger than with the 26 June 1974 conditions; here it is on the order of 40 to 50 percent. The overall ozone maximum occurs in the same grid, but it is notably perturbed (about 33 percent).

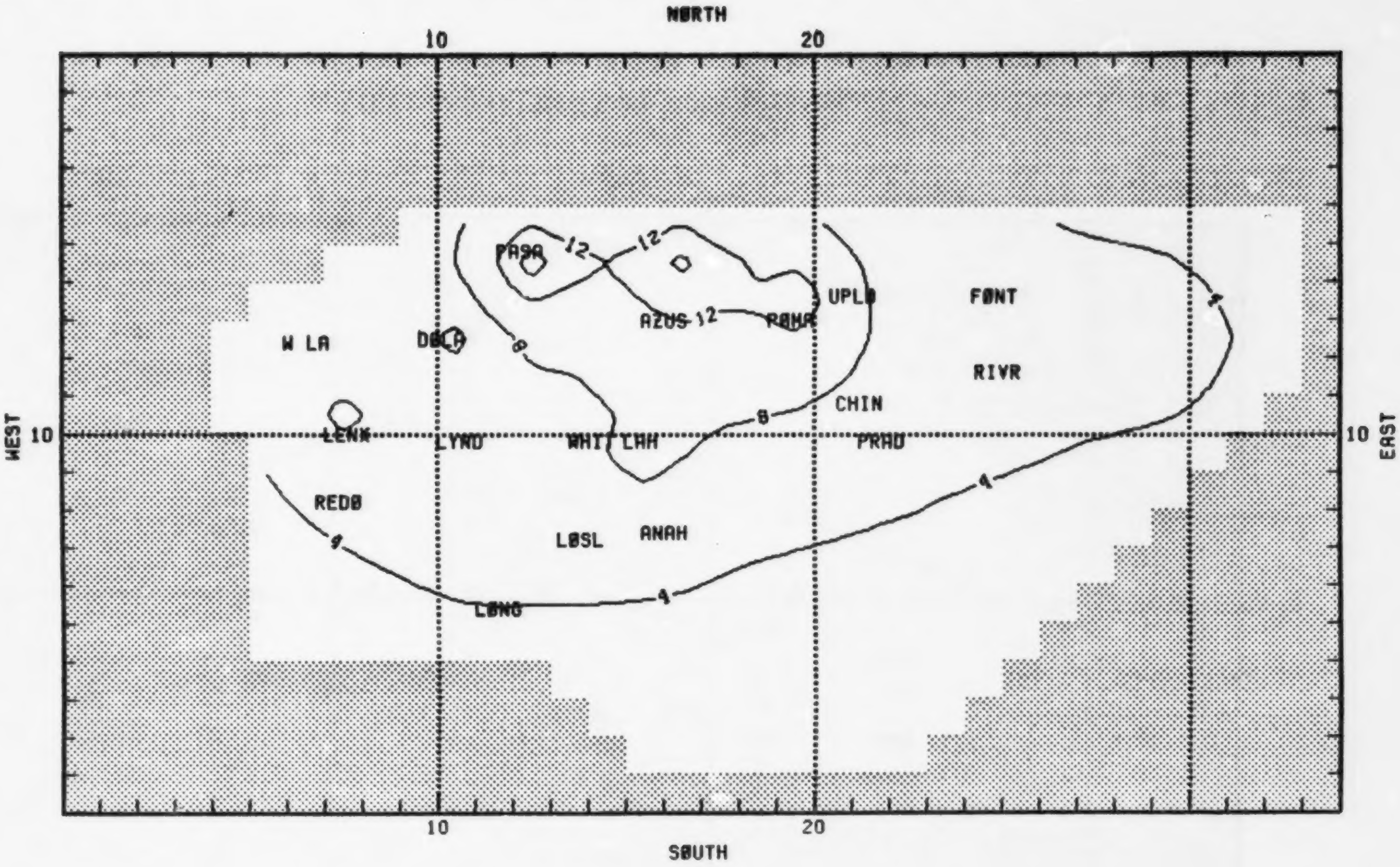
The value of the temporal correlation coefficient is relatively low, especially for ozone levels above 20 pphm; the average ozone peak time lag, however, is on the order of an hour. The dosage is the most sensitive measure (a perturbation of about 95 percent.)

2) Sensitivity of Model Input Variables to Input Data

The choice of the formula to define nonmethane hydrocarbon initial concentrations affects the hydrocarbon concentration field, as shown in figure A-37. The perturbation is not as large as in case 9, and it is mainly located in the northern central part of the basin. Lower hydrocarbon initial concentrations are obtained in the sensitivity case, i.e., with $[NMHC]/[NO_x] = 7$, than in the base case. For instance, at Pomona, the reactive hydrocarbon concentration is 1.6 ppm in the base case and 1.2 ppm in the sensitivity case.

3) Sensitivity of Ozone Levels to Hydrocarbon Initial Concentrations

Isopleths of maximum ozone deviations are shown in figure A-38. Lower ozone levels are observed throughout the basin, with the largest deviations occurring in the upper central part of the basin, from Pasadena to Riverside. This area corresponds to the largest perturbation in the initial hydrocarbon concentrations. As in the previous case, lower hydrocarbon concentrations lead to lower ozone levels in the Los Angeles basin.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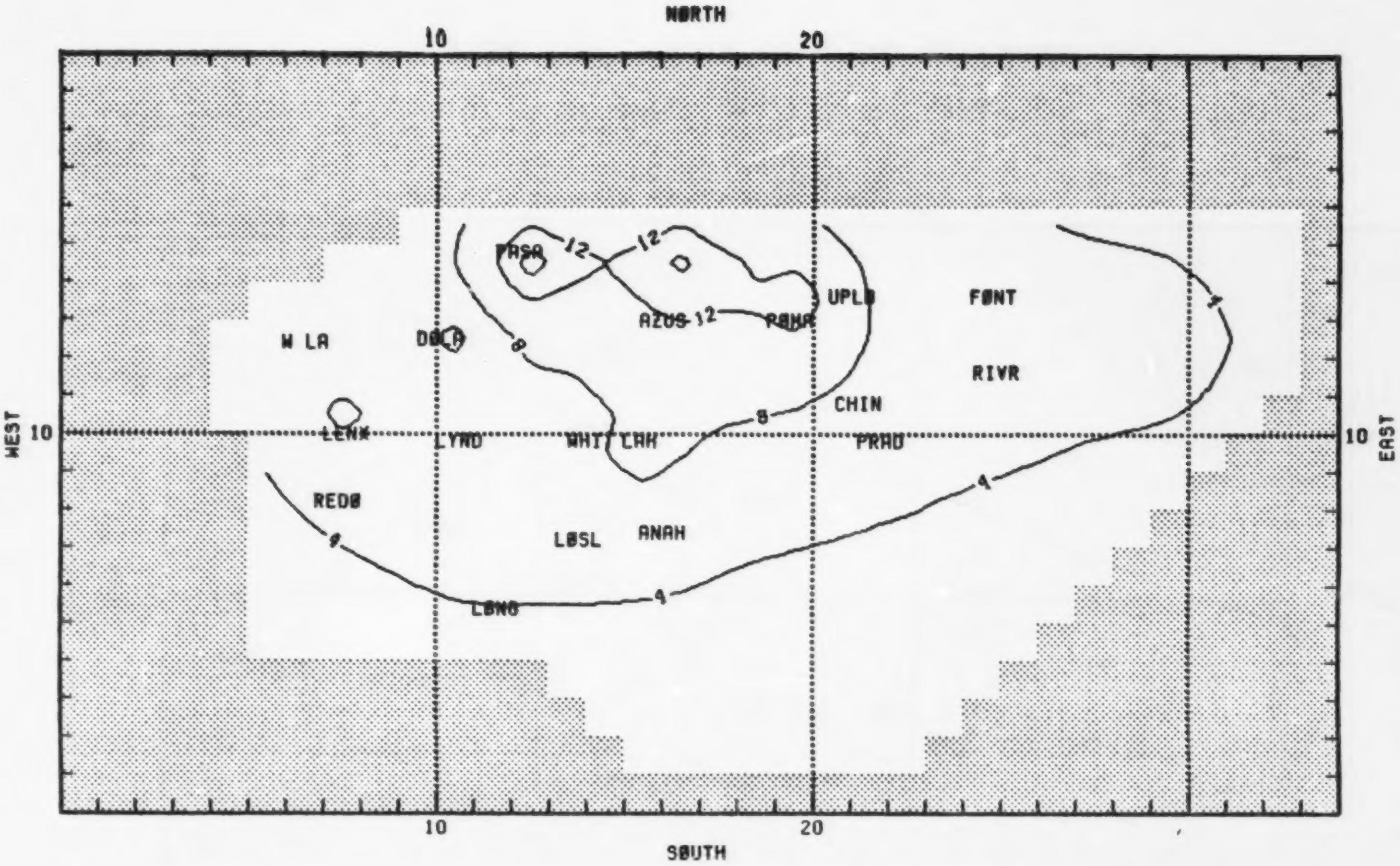
(a) Base Case NO_x (pphm)

FIGURE A-37. INITIAL CONDITIONS FOR 4 AUGUST 1975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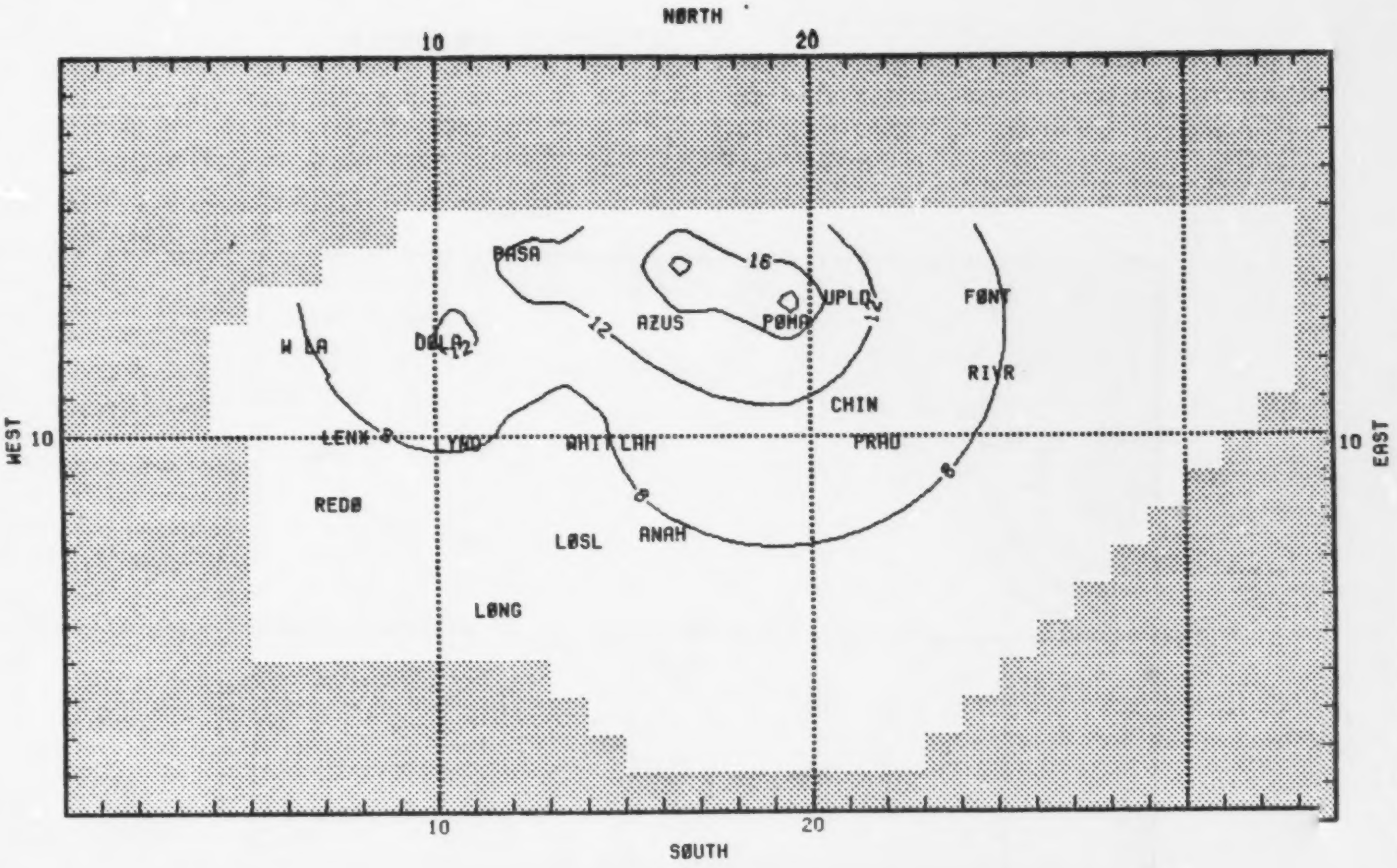
(b) Sensitivity Case 10 NO_x (pphm)

FIGURE A-37 (Continued)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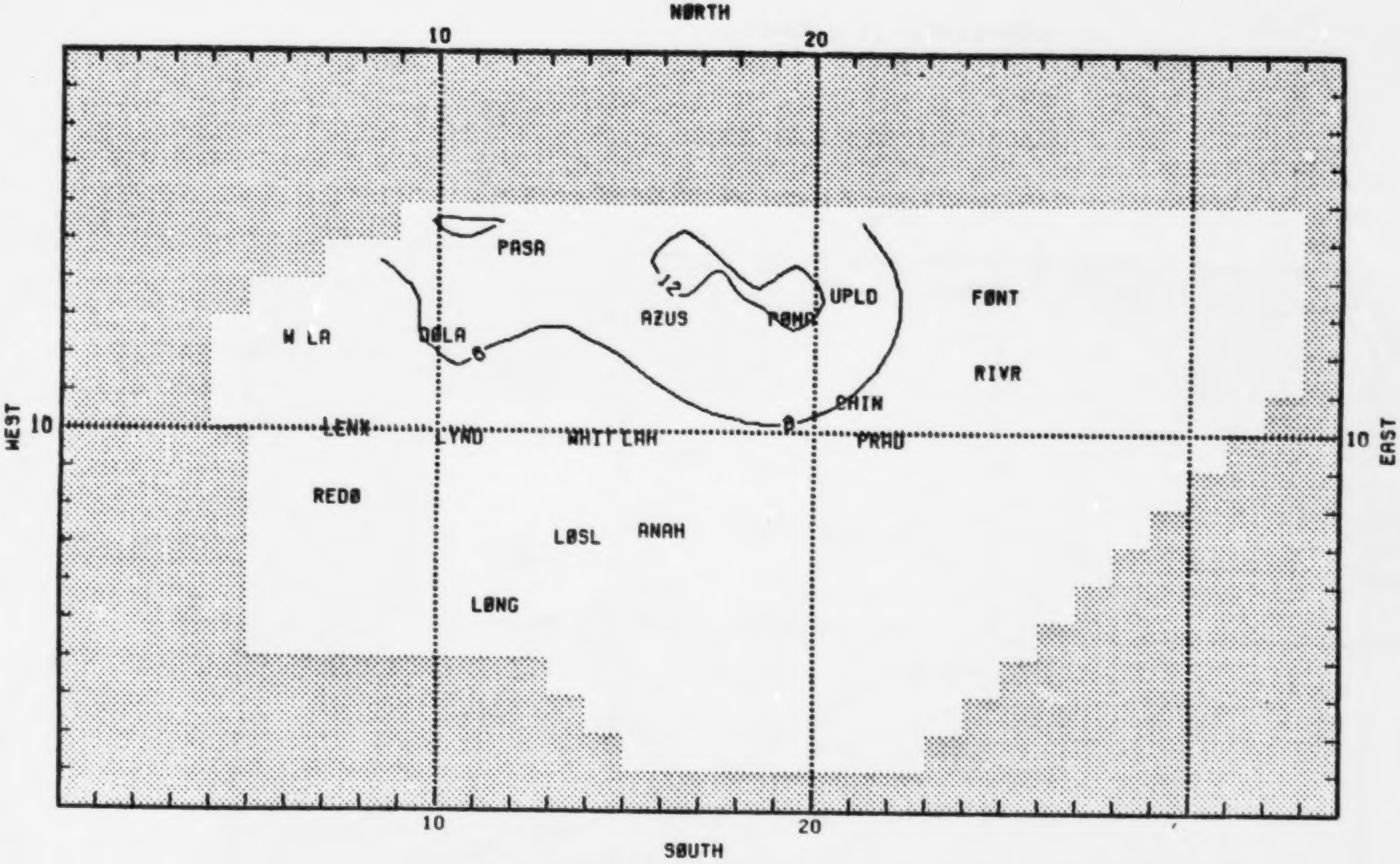
(c) Base Case RHC (pptm)

FIGURE A-37 (Continued)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(d) Sensitivity Case 10 RMC (pptm)

FIGURE A-37 (Concluded)

TABLE A-14. GENERAL SENSITIVITY MEASURES--CASE 10

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	$O_3 > 12$ pphm	$O_3 > 20$ pphm	$O_3 > 12$ pphm	$O_3 > 20$ pphm
Signed deviation	-0.450	-0.486	-0.443	-0.463
Absolute deviation	0.450	0.486	0.443	0.463
Temporal correlation	0.680	0.280	0.722	0.336
Spatial correlation	0.578	0.990	0.806	0.872

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	0.523	0.670
Peak level (pphm):		
Sensitivity case	13.8	24.8
Base case	26.3	37.0
Corresponding locations:		
Sensitivity case	Upland	30 - 16
Base case	Pomona	30 - 16

TABLE A-14 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.394	0.476
Peak time lag (hrs)	1.0	0.81

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
0.95	450	8,750

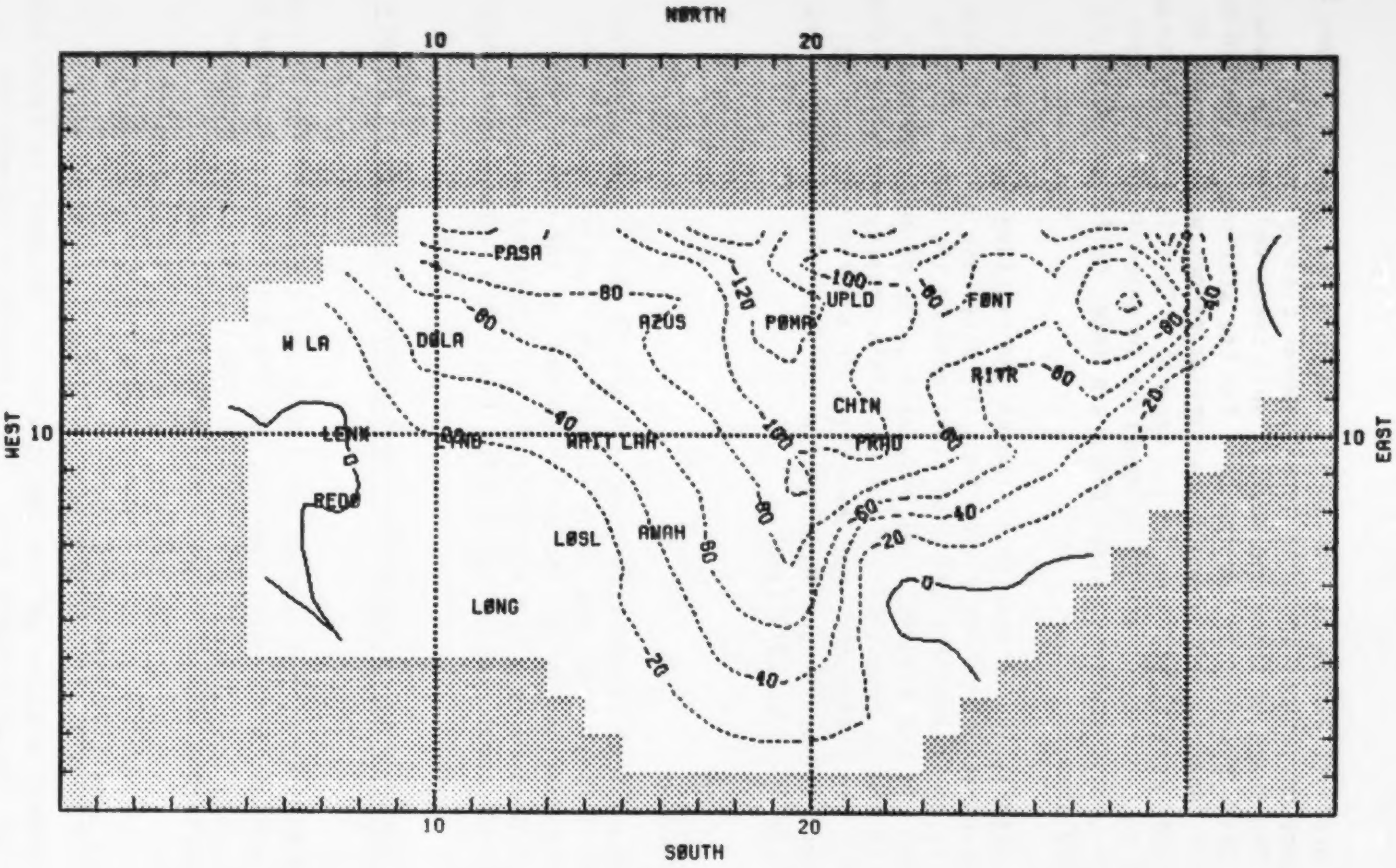
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FIGURE A-38. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS(ppb): CASE 10--BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST

Ozone profiles at six air monitoring stations are shown in figure A-39. The large deviations in ozone levels appear clearly in these profiles. The shape of the ozone peak is well conserved for the downwind stations. This, however, is not the case for the stations located in the western basin (Anaheim and Lynwood). A similar effect was observed in case 9 with the coastal stations (e.g., Laguna). This is probably because the initial concentrations are more important in determining the ozone profiles for upwind stations, since there are fewer pollutant emissions affecting the area.

It is interesting to note that, though the reactive hydrocarbon initial concentrations do not differ from the base case as much in case 10 as in case 9, the meteorological conditions enhance the effect of this perturbation. In the 4 August 1975 simulation, the mixing depths are lower than in the 26 June 1974 simulation. This creates a smaller volume of mixing for the pollutants, and the effect of a perturbation in pollutant concentrations is more important in the case of a smaller volume (i.e., for the 4 August 1975 case).

4) Conclusions

It appears from sensitivity studies 9 and 10 that, under different meteorological conditions, the definition of the reactive hydrocarbon initial concentrations is an important component of the model. This suggests the need for an accurate procedure to determine atmospheric nonmethane hydrocarbon concentrations for input into urban airshed models.

k. Model Sensitivity to Hydrocarbon Speciation--Simulation of 26 June 1974

In the base case, hydrocarbon speciation was considered for various source categories (e.g., motor vehicle, boilers distillate oil, crude oil evaporation, dry cleaning, etc.). In this sensitivity case, a common average hydrocarbon speciation was considered for all sources.

1) General Sensitivity Measures

Some general measures of the sensitivity of the model to hydrocarbon speciation are listed in table A-15. The averaging of hydrocarbon speciation among source categories leads to slightly higher ozone levels. The overall maximum ozone level and the temporal and spatial

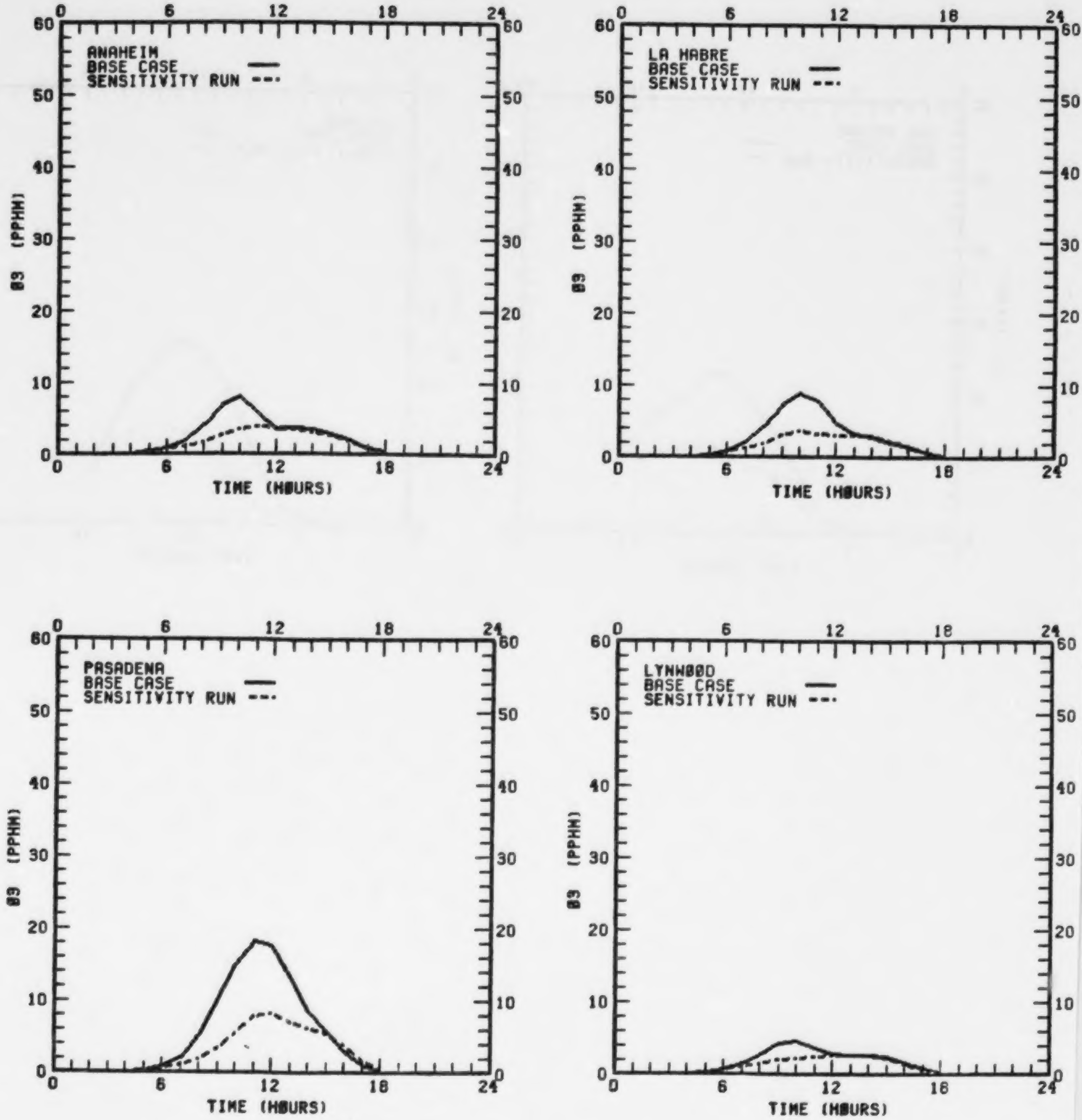


FIGURE A-39. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 10

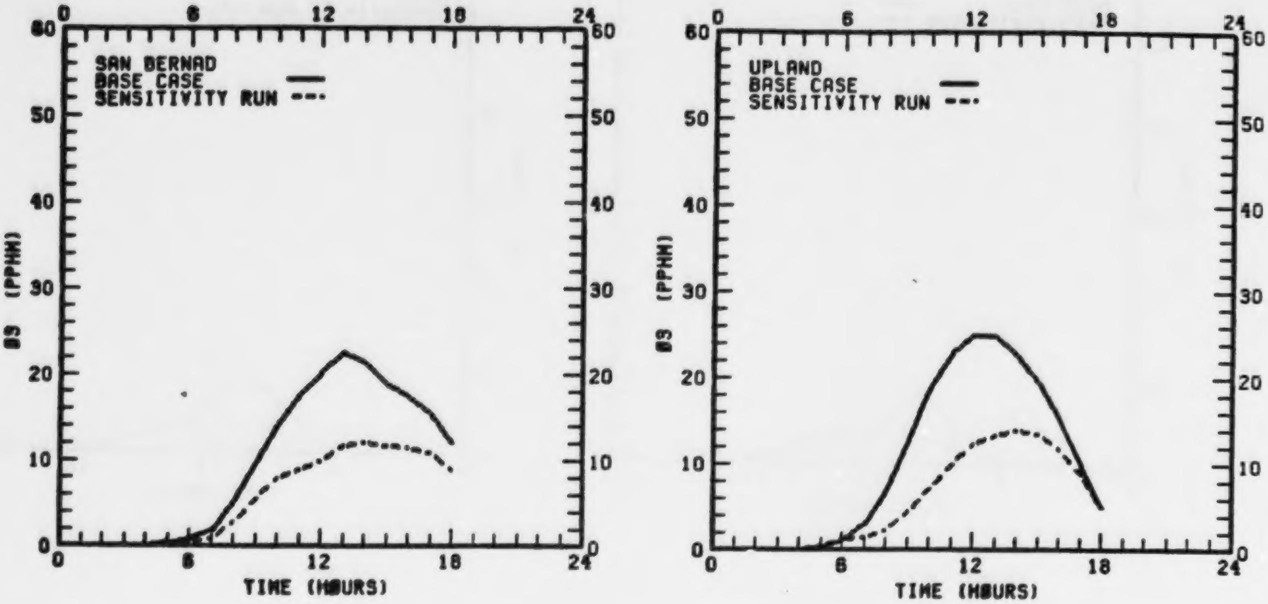


FIGURE A-39 (Concluded)

TABLE A-15. GENERAL SENSITIVITY MEASURES--CASE 11

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	$O_3 > 12$ pphm	$O_3 > 20$ pphm	$O_3 > 12$ pphm	$O_3 > 20$ pphm
Signed deviation	0.046	0.035	0.022	0.041
Absolute deviation	0.046	0.035	0.039	0.041
Temporal correlation	0.989	0.990	0.984	0.985
Spatial correlation	0.985	0.979	0.983	0.982

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	1.023	1.018
Peak level (pphm):		
Sensitivity case	36.3	39.6
Base case	35.5	38.9
Corresponding locations:		
Sensitivity case	Azusa	19 - 15
Base case	Azusa	33 - 14

TABLE A-15 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.114	0.092
Peak time lag (hrs)	0.30	0.44

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
0.138	11,375	10,000

correlations are the least affected measures in this sensitivity study. The dosage appears to be the most sensitive measure (about 14 percent deviation).

2) Sensitivity of Model Input Variables to Input Data

Two important sources of hydrocarbons in the Los Angeles basin are automobile exhausts and refineries. The averaged hydrocarbon speciation is similar to the speciation of automobile exhausts; refineries speciation differs from the former. Some hydrocarbon speciations are listed in table A-16.

In the sensitivity case, refinery emissions will have higher levels of olefins, aromatics, aldehydes and ethylene (except for aldehydes in boilers distillate oil); motor vehicle exhaust will present only a small decrease in aromatics emissions. Olefins, aromatics and aldehydes are oxidized in the atmosphere faster than paraffins; consequently, they are better precursors of photochemical smog. Therefore, one should expect higher ozone levels in the area downwind of the refineries and negligible changes in the areas where automotive exhausts predominate.

3) Sensitivity of Ozone Levels to Hydrocarbon Speciation

Isopleths of maximum ozone deviation are shown in figure A-40. There is an area of higher ozone levels for the sensitivity case. This area centers around Whittier and La Habra, downwind of the refineries that are located around Long Beach. Therefore, this effect results directly from the increase of reactive hydrocarbons such as olefins, aromatics and aldehydes in the refinery emissions.

The northern part of the basin is affected most by motor vehicle exhausts from downtown Los Angeles and the surrounding freeways. Accordingly, little perturbation occurs in the model predictions.

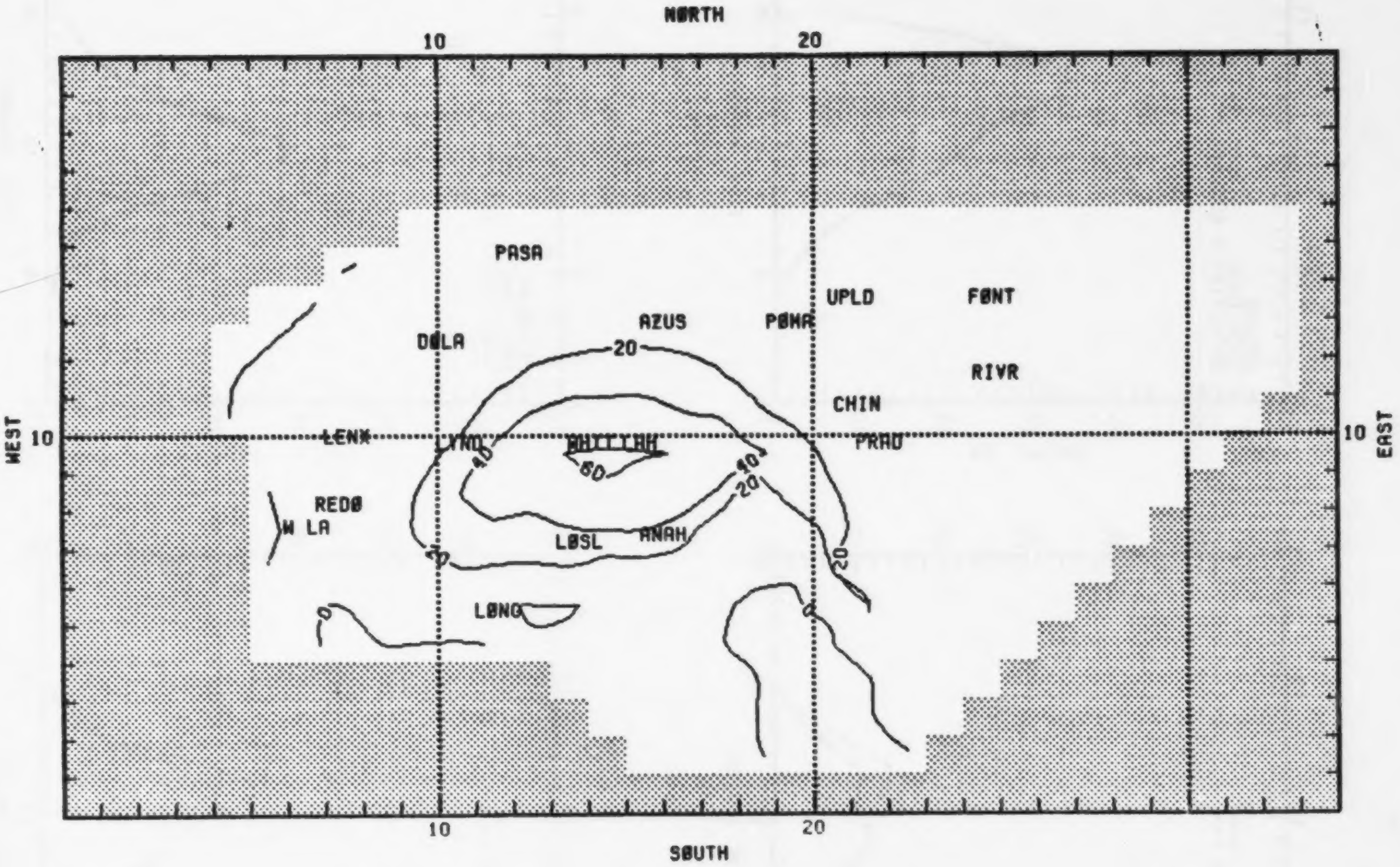
Ozone profiles for six air quality monitoring stations, which are presented in figure A-41, confirm these results. Higher ozone levels are observed for the sensitivity case at Anaheim, La Habra, and Lynwood; negligible changes occur at Pasadena, Upland, and San Bernardino.

4) Conclusions

The use of a common hydrocarbon speciation for all source categories does not affect strongly the overall predictions of the model. However, TABLE A-16. HYDROCARBON SPECIATION OF SOME SOURCE CATEGORIES

(mole/g)

Source Category	Olefins (except Ethylene)	Paraffins	Aromatics	Aldehydes	Ethylene
Boilers distillate oil	0.0	0.0352	0.0	0.0162	0.0
Crude oil evaporation (fixed roof)	0.0	0.0531	0.000152	0.0	0.0
Motor vehicles	0.00123	0.0435	0.00280	0.00184	0.00123
Sensitivity case	0.0016	0.044	0.0018	0.0017	0.00097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LENX
LYND
WHTT
LAH
PRAD
REDØ
W LA
LØSL
ANAH
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40
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FIGURE A-40. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 11--BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST

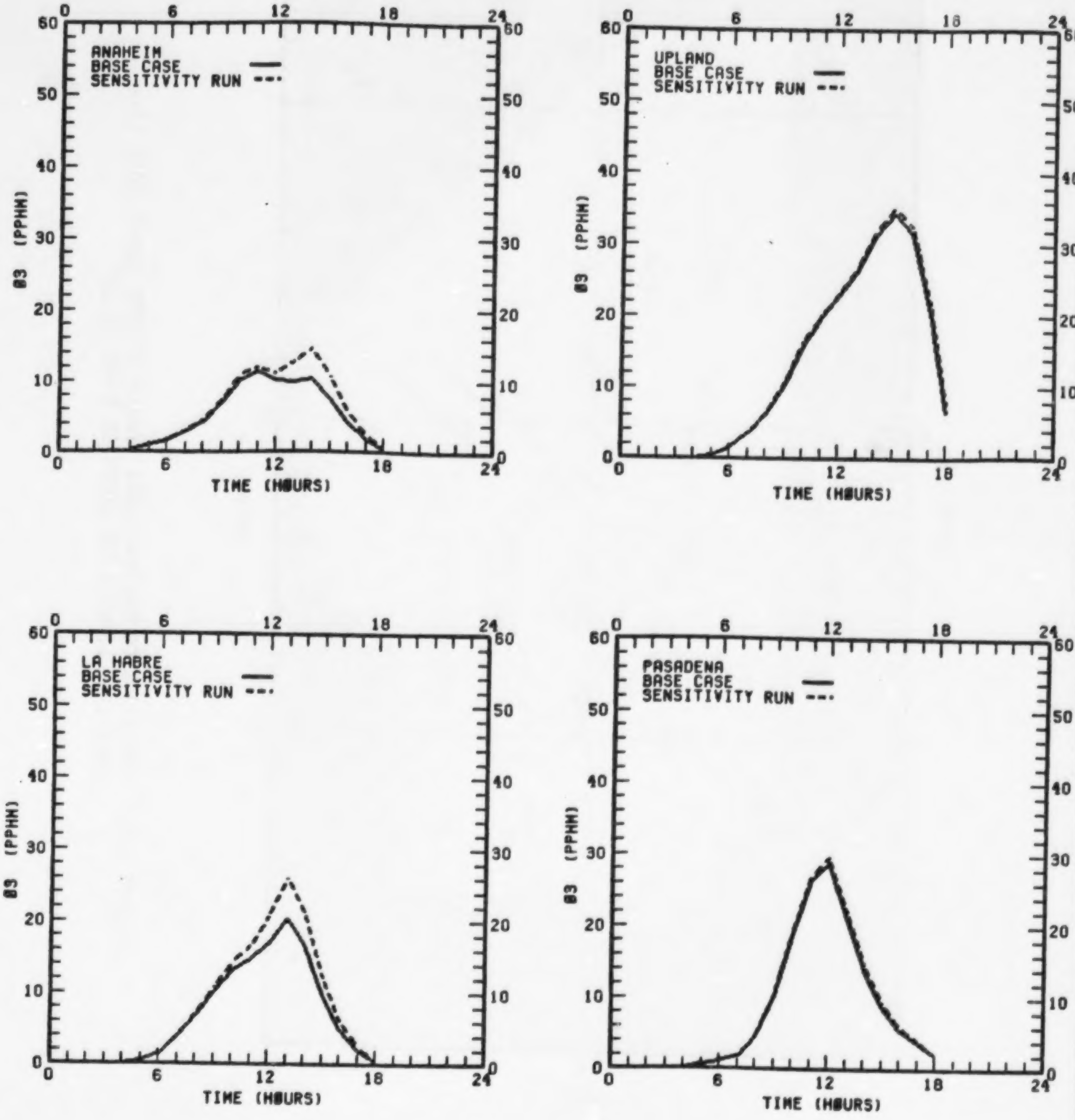


FIGURE A-41. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 11

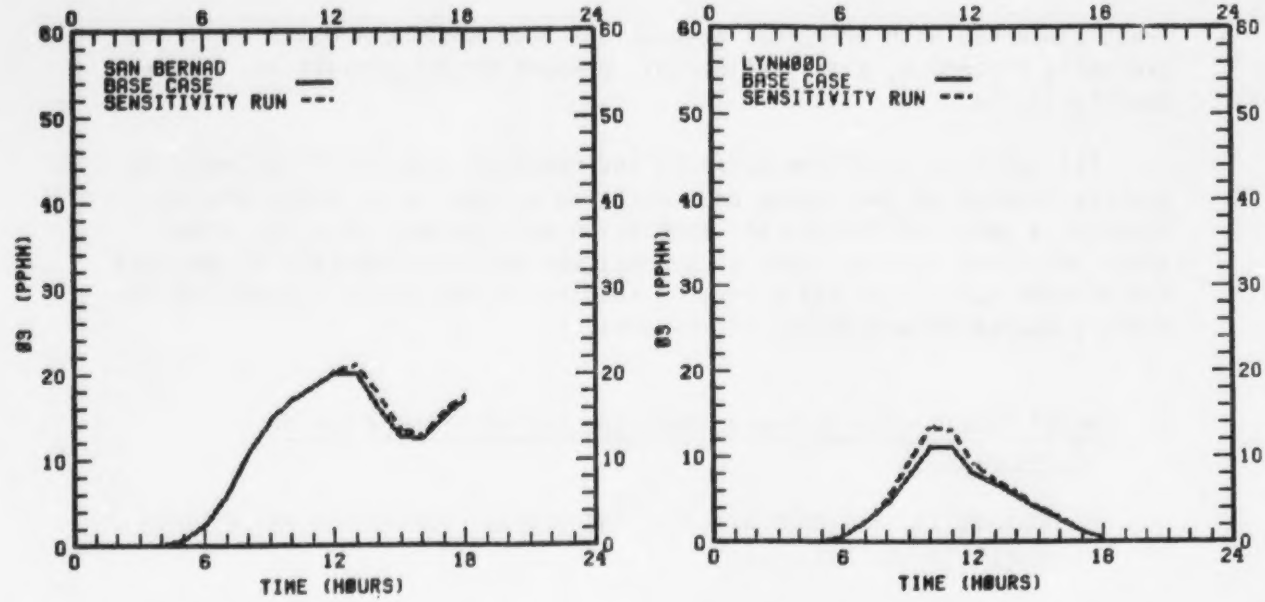


FIGURE A-41 (Concluded)

areas concerned with precursor speciations that have been modified in the averaging procedure, e.g., refineries, present notable deviations in air quality levels.

The sensitivity of the model to the chemical composition of emission sources depends on the nature and spatial distribution of these sources. Clearly, a detailed hydrocarbon speciation will be desirable for urban areas involving various types of hydrocarbon emission sources; an averaged hydrocarbon speciation may give good results if one source category is the primary source of precursors in the area.

1. Model Sensitivity to Hydrocarbon Speciation--Simulation of 4 August 1975

As in case 11, a common averaged hydrocarbon speciation was defined for all source categories.

1) General Sensitivity Measures

As with the 26 June 1974 conditions, higher ozone levels are observed with the common hydrocarbon speciation (see table A-17). In general, larger deviations are observed. The dosage is the most sensitive measure (about 60 percent larger in the sensitivity case). The overall maximum ozone level is not much affected in this study, since it is located in an area that is only slightly perturbed by the hydrocarbon speciation (see figure A-42). The temporal correlation is high (above 0.950), but the spatial correlation is slightly lower (0.8 for the station statistics).

2) Sensitivity of Model Input Variables to Input Data

The modification in the source emissions resulting from the averaging of hydrocarbon speciation has been presented for case 11.

3) Sensitivity of Ozone Levels to Hydrocarbon Speciation

Deviations of maximum ozone between the sensitivity case and the base case are shown in figure A-43. A wider area is affected than in the 26 June 1974 case. Also, higher ozone deviations are observed. The fact that mixing depths are lower for the 4 August 1975 case than for the 26 June 1974 case (e.g., 324.6 m at Azusa between 12 and 13 L.S.T. for this case and 594.2 m for case 11), increases the effect of the perturbation, since the mixing volume is reduced.

TABLE A-17. GENERAL SENSITIVITY MEASURES--CASE 12

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	$O_3 > 12$ pphm	$O_3 > 20$ pphm	$O_3 > 12$ pphm	$O_3 > 20$ pphm
Signed deviation	0.121	0.085	0.138	0.090
Absolute deviation	0.125	0.085	0.142	0.091
Temporal correlation	0.969	0.961	0.966	0.958
Spatial correlation	0.818	0.940	0.923	0.856

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	1.128	1.003
Peak level (pphm):		
Sensitivity case	29.7	37.2
Base case	26.3	37.0
Corresponding locations:		
Sensitivity case	Pomona	30 - 16
Base case	Pomona	30 - 16

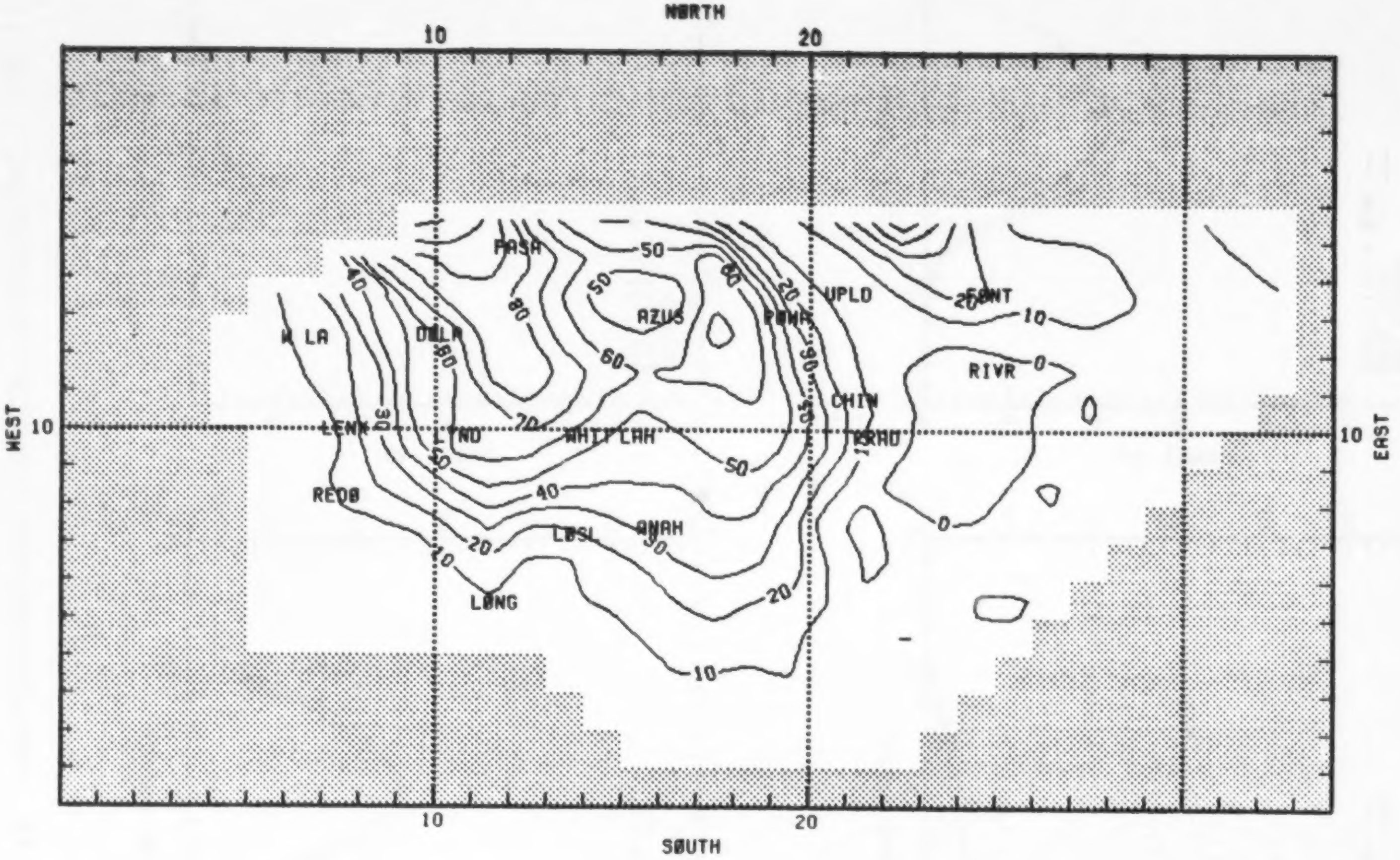
TABLE A-17 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.303	0.313
Peak time lag (hrs)	0.25	0.39

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
0.597	13,975	8,750



NORTH
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SOUTH
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LYND
WHIT
LAH
REDO
LOSL
ANAH
LONG
10
20
30
40
50
60
70
80
0

FIGURE A-42. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 12--BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST

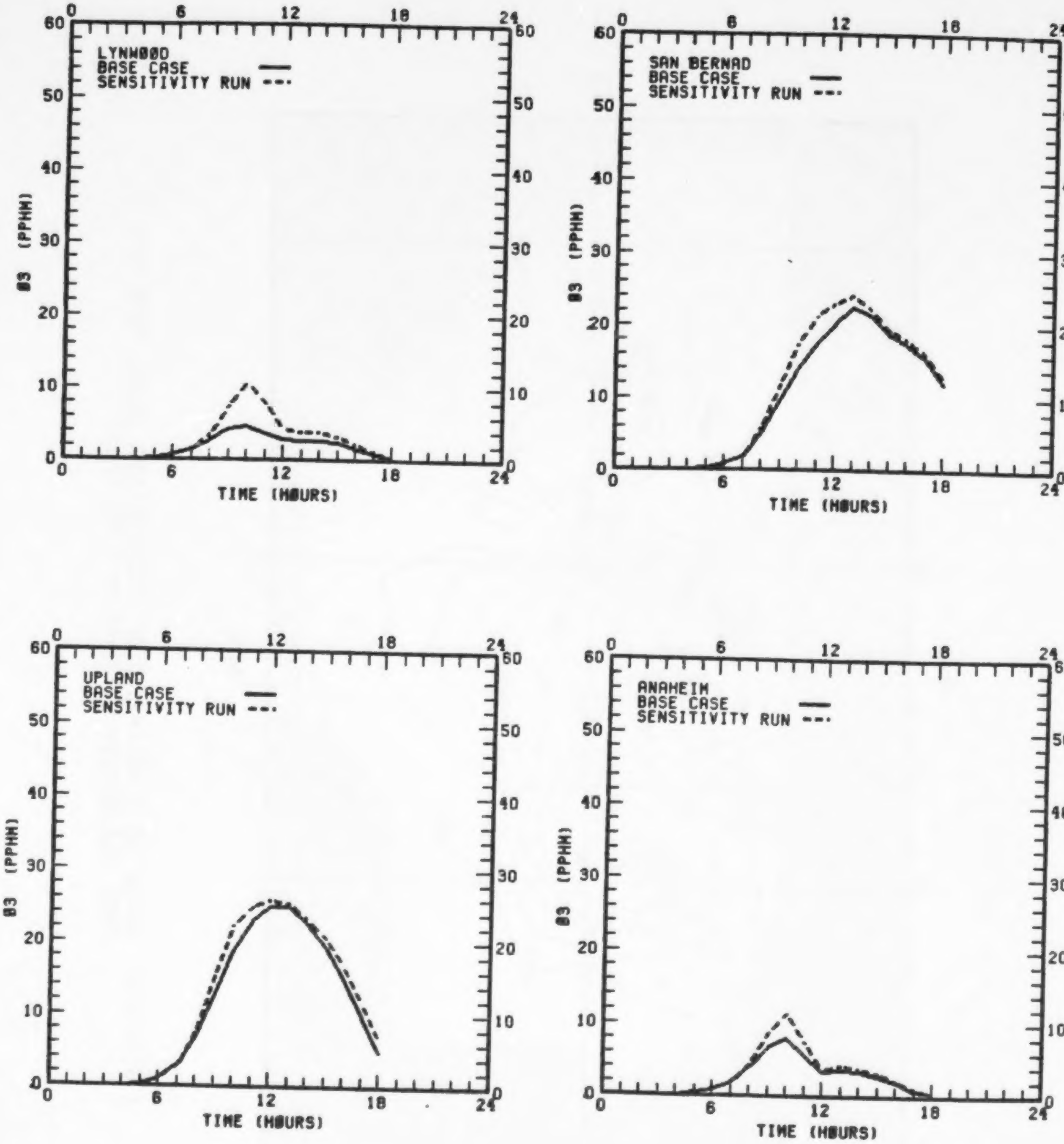


FIGURE A-43. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 12

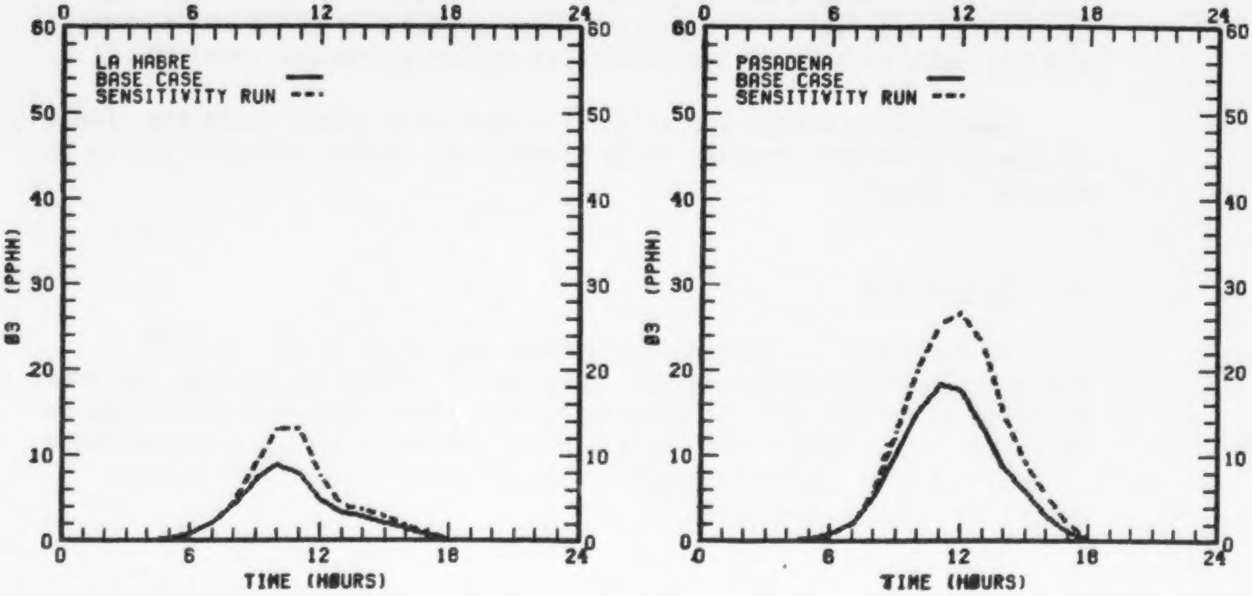


FIGURE A-43 (Concluded)

Profiles of ozone concentrations at six monitoring stations are shown in figure A-43. When these are compared with figure A-41, it appears that the perturbations are more important in this case. The effect of the hydrocarbon speciation is transported far downwind from the refineries, and the ozone profile at San Bernardino presents some perturbation.

Lower mixing depths and slightly higher wind speeds cause the effect of the emission perturbation to be transported farther downwind and to be more pronounced.

4) Conclusions

It was shown in the previous sensitivity study (case 11) that averaging hydrocarbon speciation among source categories affects the areas downwind of refineries. It appears in this study that this effect may be important and extended to a large part of the basin when the perturbation is combined with appropriate meteorological conditions (lower mixing depths and higher wind speeds).

m. Model Sensitivity to Mobile Source Emissions: Older Inventory--Simulation of 26 June 1974

In this sensitivity study an older mobile source inventory was used. This will affect nitrogen oxides, hydrocarbons and carbon monoxide emissions from mobile sources.

1) General Sensitivity Measures

Some measures of the general sensitivity of the model are listed in table A-18. The overall sensitivity of the urban airshed is not much affected in this sensitivity study. The most sensitive measure is the dosage (11 percent higher). In general, higher ozone levels are obtained, but the deviations from the base case remain below 4 percent. The overall maximum ozone level occurs at the same location, and it is not perturbed notably. The values of the spatial and temporal correlation coefficients are high (above 0.969).

2) Sensitivity of Model Input Variables to Input Data

Mobile source emissions have been slightly perturbed by the use of an older inventory. Isopleths of daily ground level emissions of nitrogen oxides and hydrocarbons are presented in figure A-44 for this case and the

TABLE A-18. GENERAL SENSITIVITY MEASURES--CASE 13

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	$O_3 > 12$ pphm	$O_3 > 20$ pphm	$O_3 > 12$ pphm	$O_3 > 20$ pphm
Signed deviation	0.027	0.022	0.022	0.018
Absolute deviation	0.037	0.029	0.039	0.034
Temporal correlation	0.988	0.987	0.984	0.977
Spatial correlation	0.983	0.969	0.983	0.975

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	1.020	1.027
Peak level (pphm):		
Sensitivity case	36.2	39.9
Base case	35.5	38.9
Corresponding locations:		
Sensitivity case	Azusa	33 - 14
Base case	Azusa	33 - 14

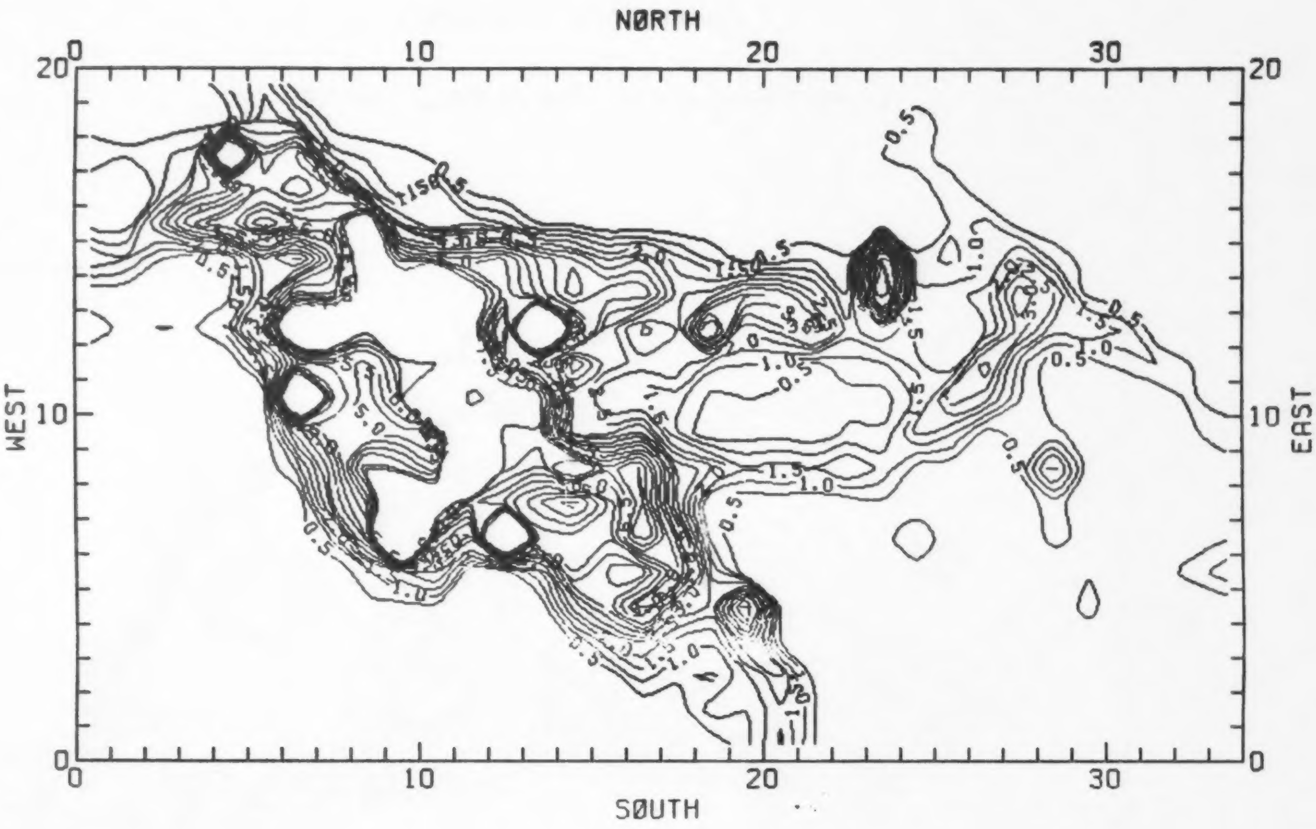
TABLE A-18 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.028	0.029
Peak time lag (hrs)	0.350	0.440

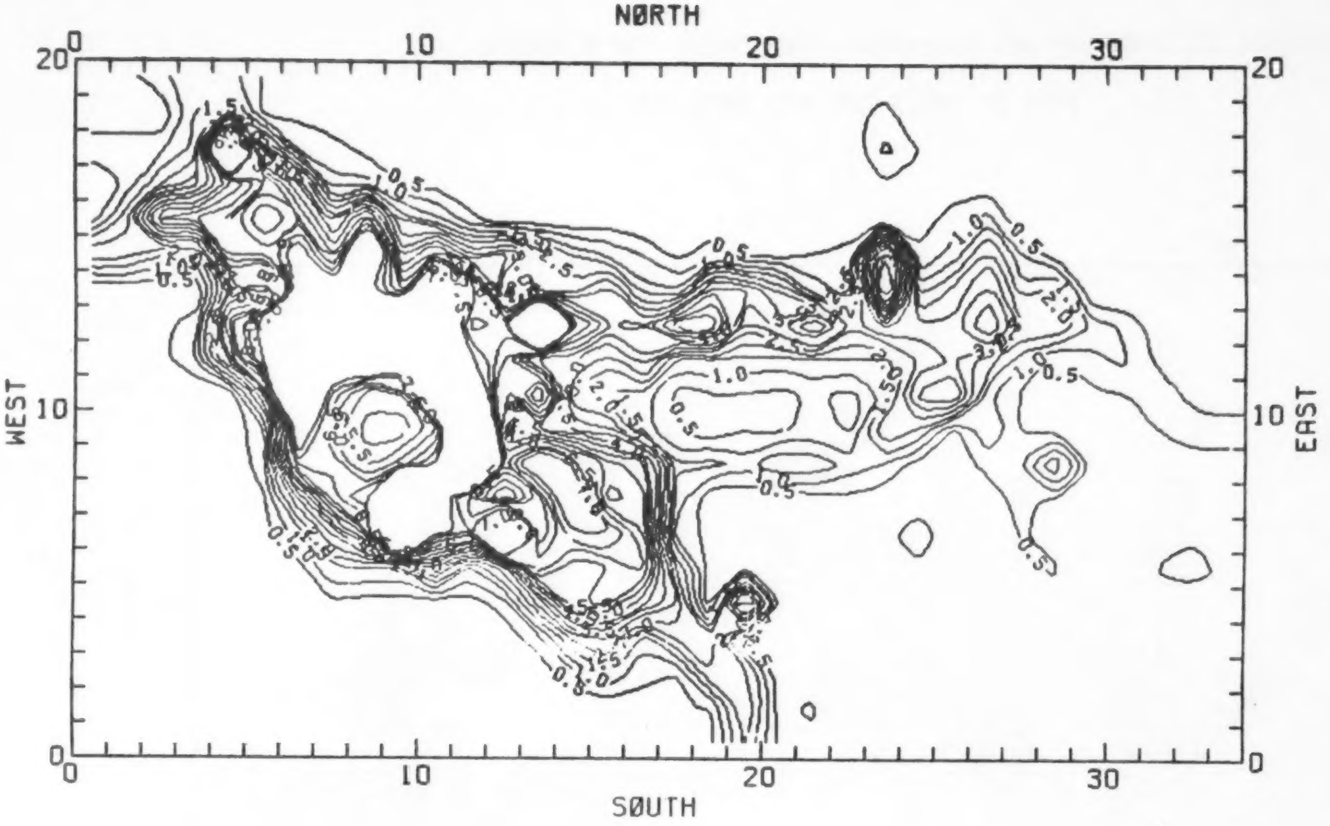
(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
0.113	11,125	10,000


NØRTH
SØUTH
WEST
EAST
0
10
20
30
0.5
1.0
1.5
3.0
5.0

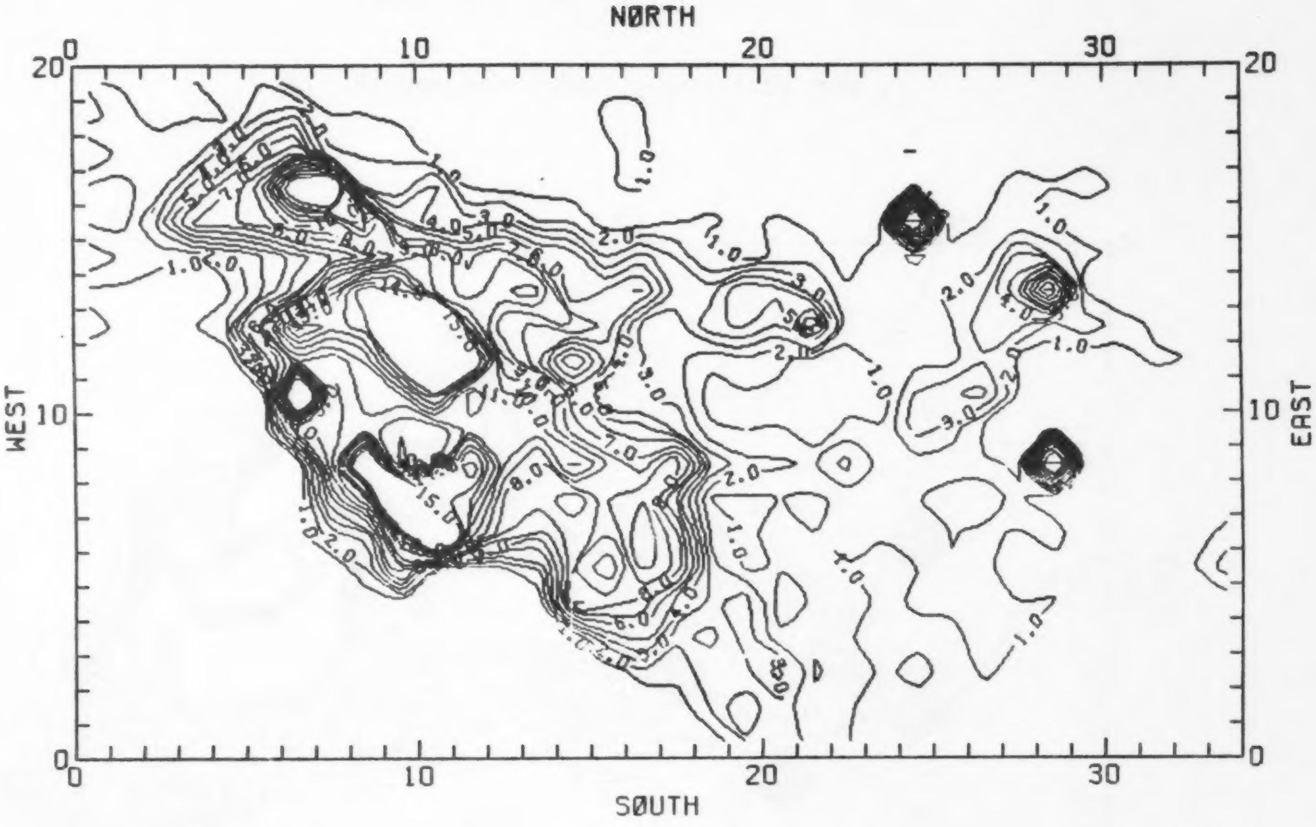
(a) Base Case NO_x (Tons of NO_2)

FIGURE A-44. TOTAL DAILY EMISSIONS FOR GROUND-LEVEL SOURCES


NØRTH
SØUTH
WEST
EAST
0
10
20
30
0.5
1.0
1.5
2.0
3.0

(b) NO_x (Tons of NO_2) Sensitivity Case 13

FIGURE A-44 (Continued)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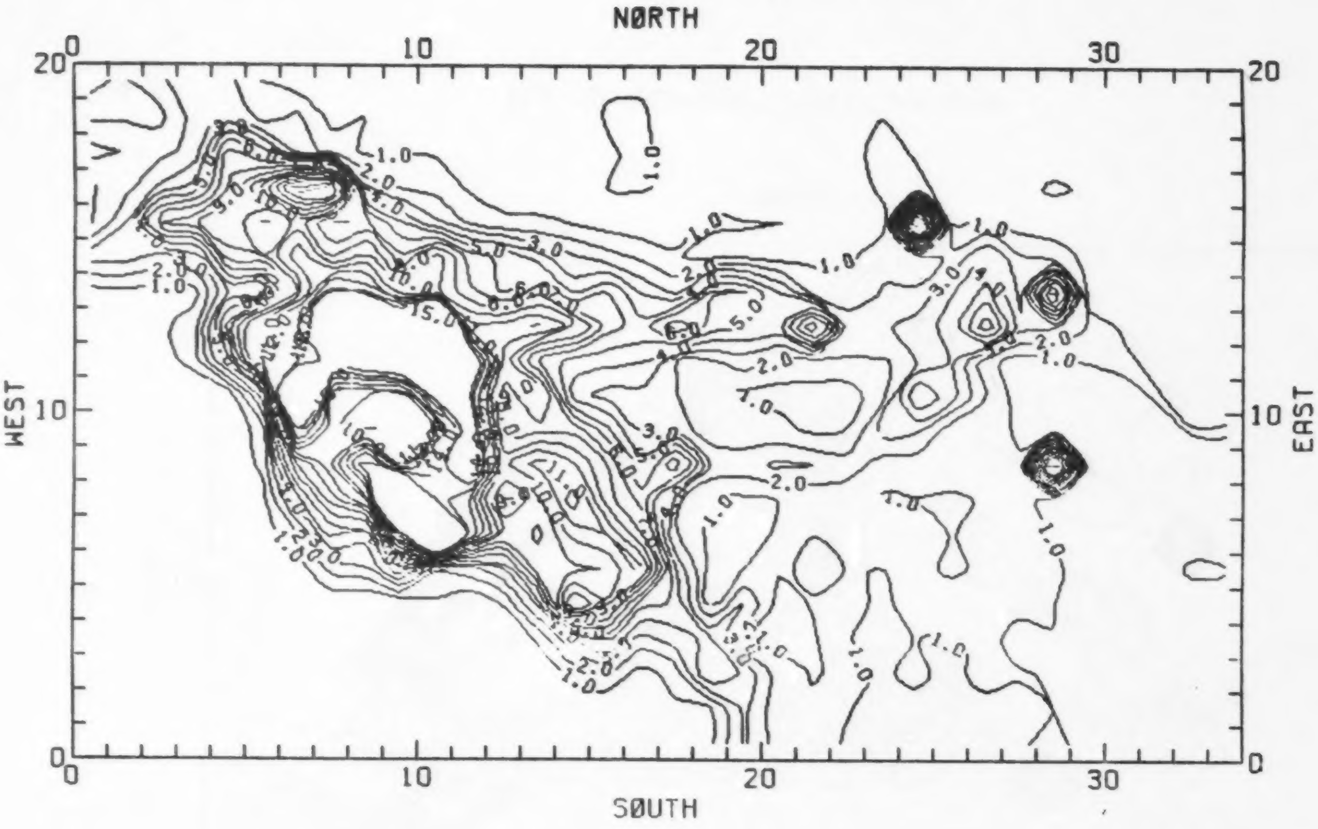
15.0

(c) Hydrocarbons (Tons) Base Case

FIGURE A-44 (Continued)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1.0
2.0
3.0
5.0
6.0
15.0

(d) Hydrocarbons (Tons) Sensitivity Case 13

FIGURE A-44 (Concluded)

corresponding base case. The major difference appears near the coast around Lennox. In general, the older emission estimate is not as detailed and results in smoother emission patterns.

3) Sensitivity of Ozone Levels to Mobile Source Emissions

Isopleths of maximum ozone deviations are shown in figure A-45. The predictions have been perturbed by less than 10 ppb. Ozone profiles at six air quality monitoring stations are shown in figure A-46. The largest deviation occurs at San Bernardino. The air parcel which reaches this station has traveled across the center part of the basin, and slight changes in the emission patterns have probably accumulated to create this perturbation in the ozone peak level. Other areas show little perturbation in ozone levels.

The emission inventories presented in figure A-44 are averaged by grid in the model simulation. It is probable that the grid averaged emissions show deviations which are too small to induce any large perturbation in the urban airshed dynamics.

4) Conclusions

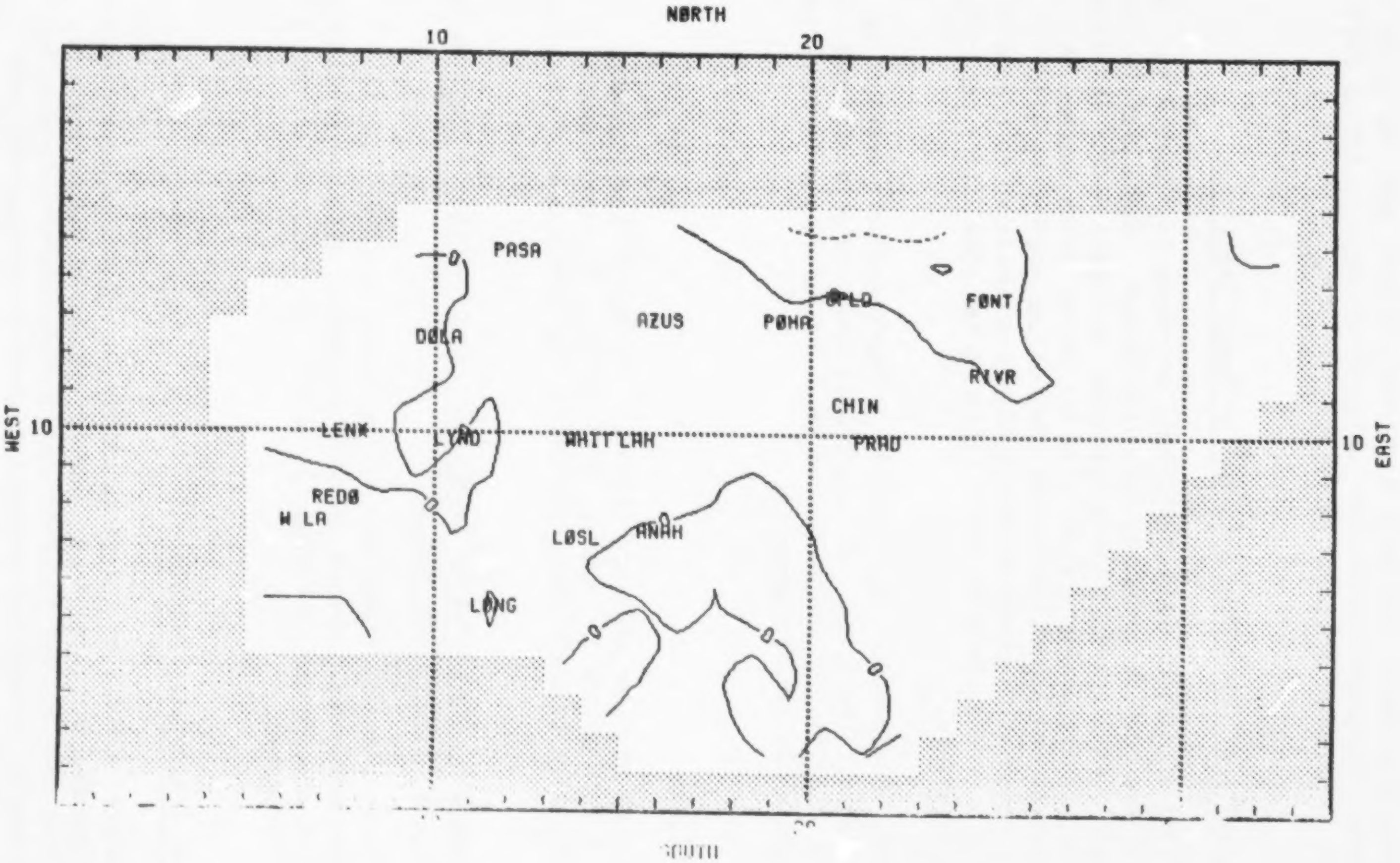
The use of an older emission inventory for mobile sources has a negligible effect on the air quality predictions. The model appears to be rather insensitive to small perturbations in the mobile source emissions.

n. Model Sensitivity to Mobile Source Emissions: Estimate Based on Gas Sales--Simulation of 26 June 1974

In this sensitivity study, the mobile source inventory has been obtained by considering averaged gas sale estimates, assuming a reasonable temporal distribution and resolving the spatial distribution according to population estimates.

1) General Sensitivity Measures

The general effects of the perturbation in the mobile source inventory are presented in table A-19. The deviations in ozone levels are more important than in case 13 (older inventory), however, they do not exceed 8.5 percent (signed and absolute deviations and maximum ozone statistics). The dosage is the most sensitive measure with an increase of 24.5 percent.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CHIN
LENX
LYND
WHITLAH
PRAD
REDØ
W LA
LØSL
ANAH
LØNG
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FIGURE A-45. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 13--BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST

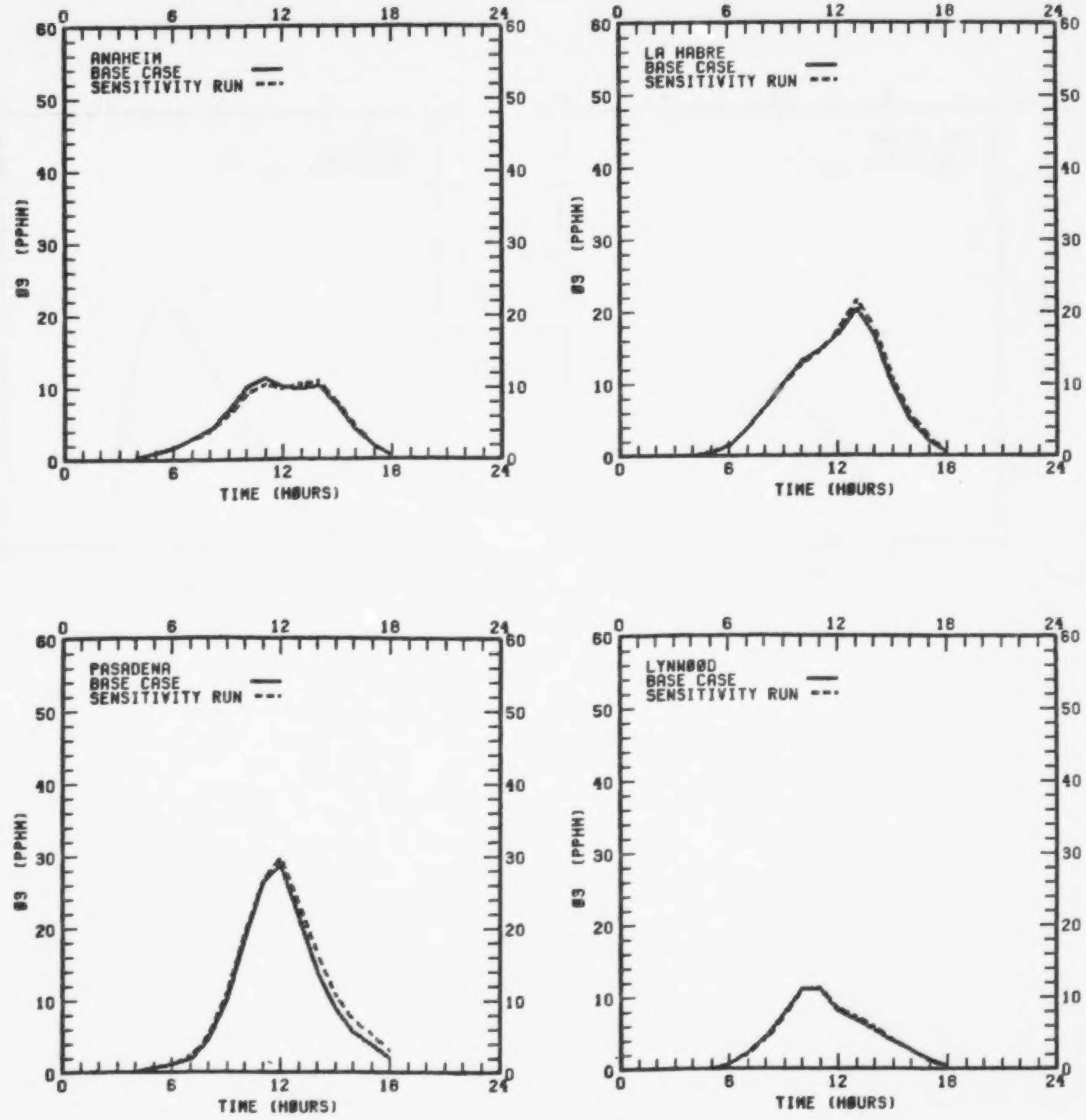


FIGURE A-46. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 13

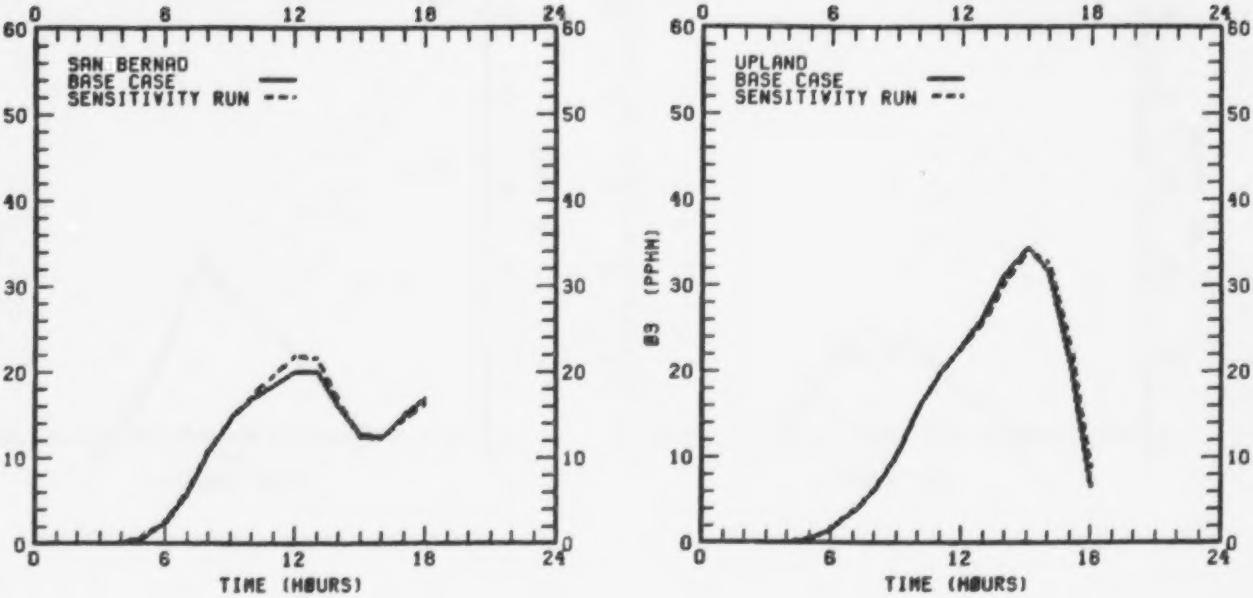


FIGURE A-46 (Concluded)

TABLE A-19. GENERAL SENSITIVITY MEASURES--CASE 14

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	$O_3 > 12$ pphm	$O_3 > 20$ pphm	$O_3 > 12$ pphm	$O_3 > 20$ pphm
Signed deviation	0.064	0.075	0.070	0.085
Absolute deviation	0.067	0.075	0.073	0.085
Temporal correlation	0.988	0.989	0.986	0.982
Spatial correlation	0.983	0.973	0.980	0.967

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	1.101	1.056
Peak level (pphm):		
Sensitivity case	39.1	41.1
Base case	35.5	38.9
Corresponding locations:		
Sensitivity case	Azusa	19 - 15
Base case	Azusa	33 - 14

TABLE A-19 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.070	0.082
Peak time lag (hrs)	0.130	0.190

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
0.245	12,450	10,000

The temporal and spatial correlations are high (above 0.967) and the peak time lag is short (an average 12 minutes for downwind stations).

In general, higher ozone levels are predicted in the sensitivity case, but the perturbations remain under 10 percent (except for the dosage).

2) Sensitivity of Model Input Variables to Input Data

The spatial and temporal distributions of the mobile source inventory have been modified. The spatial distributions of the total daily emissions of nitrogen oxides and hydrocarbons from ground level sources are shown in figure A-47 and can be compared with the base case emissions presented in figure A-43. Total daily emissions from mobile sources are presented in table A-20 for this sensitivity case and the 26 June 1974 base case. Emissions of reactive hydrocarbons and carbon monoxide are higher by about 50 percent in the sensitivity case; the perturbation in nitrogen oxides is only 6 percent. This increase of hydrocarbon emissions leads to overall higher ozone levels shown in table A-19.

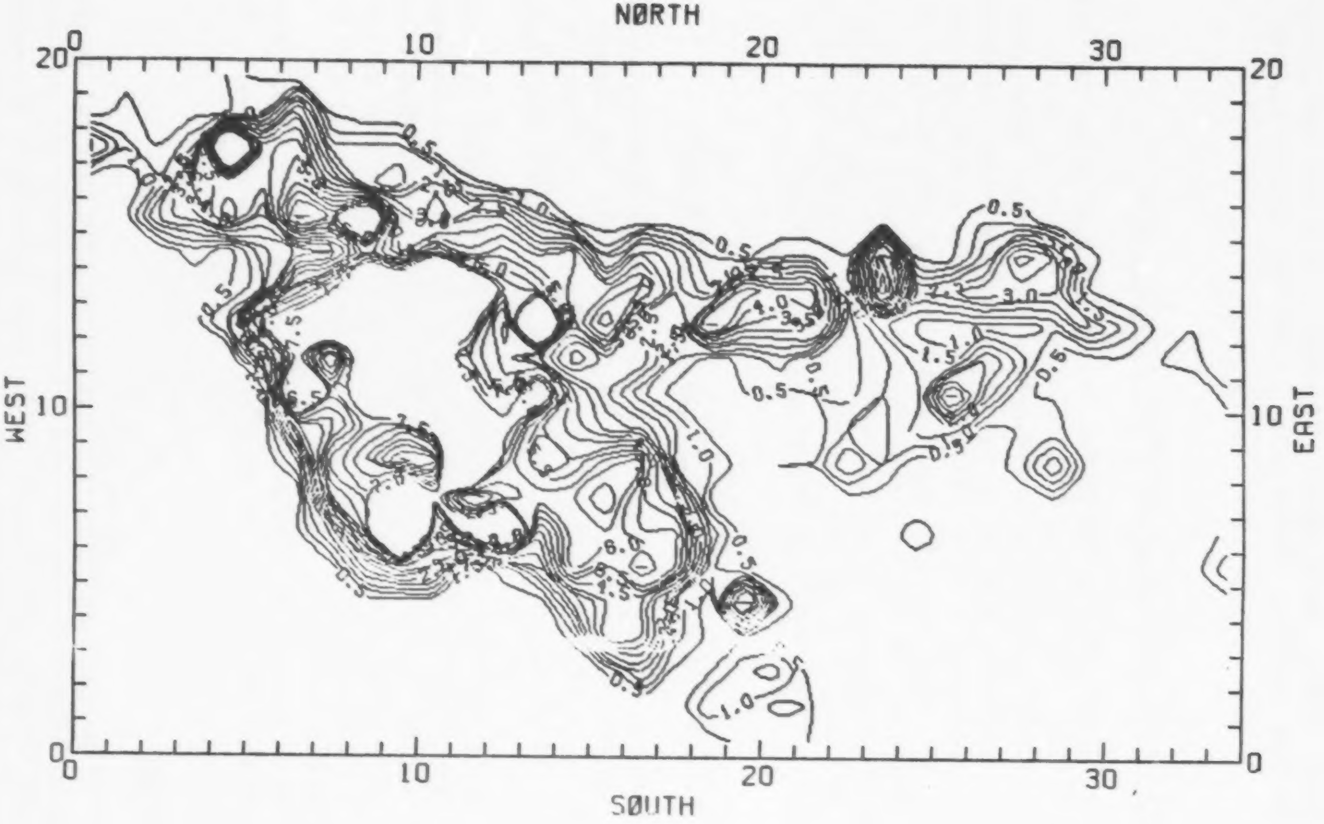
3) Sensitivity of Ozone Levels to Mobile Source Emissions

The deviations in maximum ozone concentrations between the sensitivity case and the base case are shown in figure A-48. The largest deviations occur in upper mid-basin. This appears also in figure A-49, where ozone profiles at six air quality monitoring stations are shown.

Higher ozone levels result from higher primary pollutant emissions (especially hydrocarbons) from mobile sources. Since most of the mobile sources are located in the western part of the basin around downtown Los Angeles, the areas that are most affected by this new emission pattern are downwind of the heavy traffic region. Hence, the major deviations in ozone levels are predicted to occur at Pasadena and Anaheim. As atmospheric dispersion occurs the differences decrease, as ozone profiles at stations further downwind, such as Upland and San Bernardino, indicate.

4) Conclusions

The use of gas sale estimates and population distributions to derive a mobile source inventory leads to higher emission levels and consequently to higher ozone levels, particularly in the area downwind of the heavy traffic region. However, the general perturbations do not exceed 10 percent, except for the dosage, which is 25 percent higher. This effect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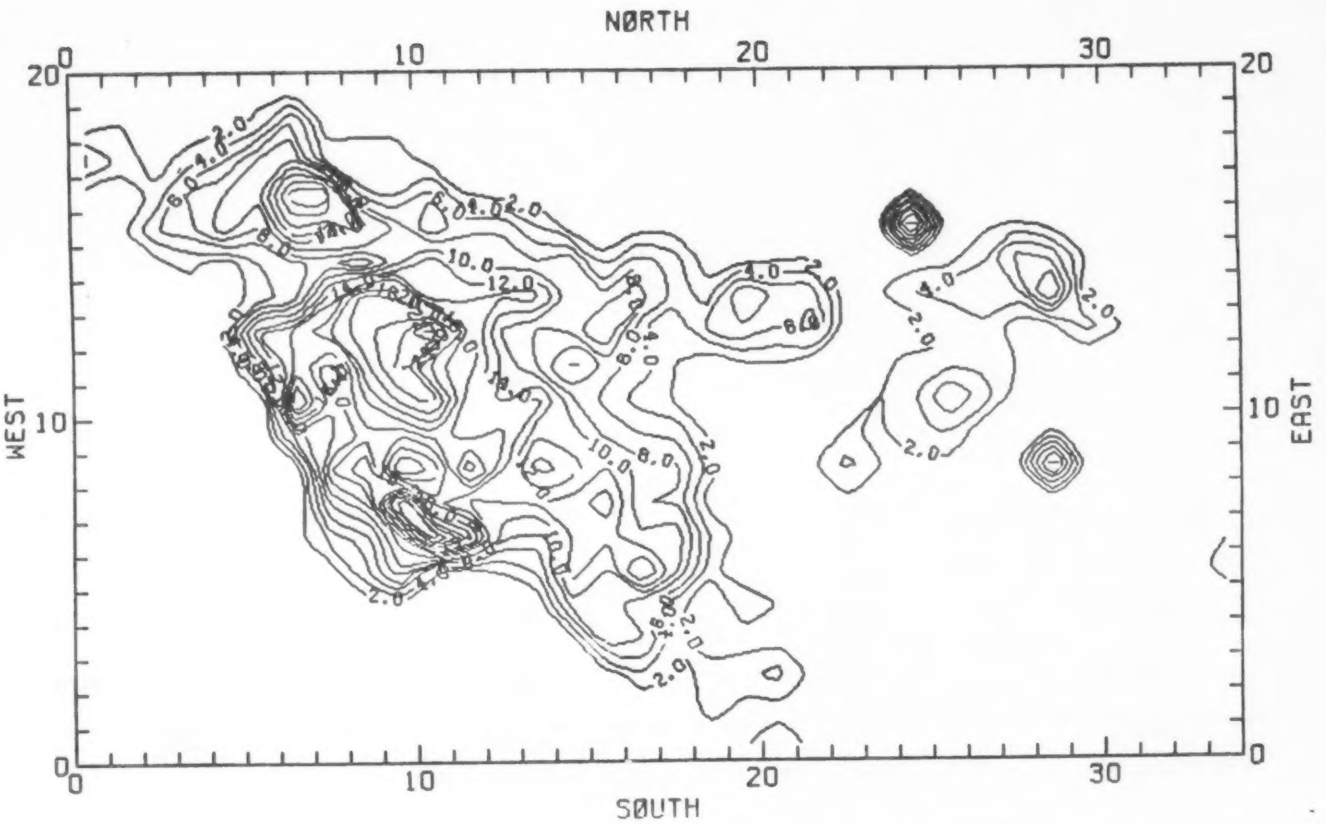
1.0
1.5
3.0
4.0
6.0

(a) NO_x (Tons of NO_2) Sensitivity Case 14

FIGURE A-47. TOTAL DAILY EMISSIONS FOR GROUND LEVEL SOURCES

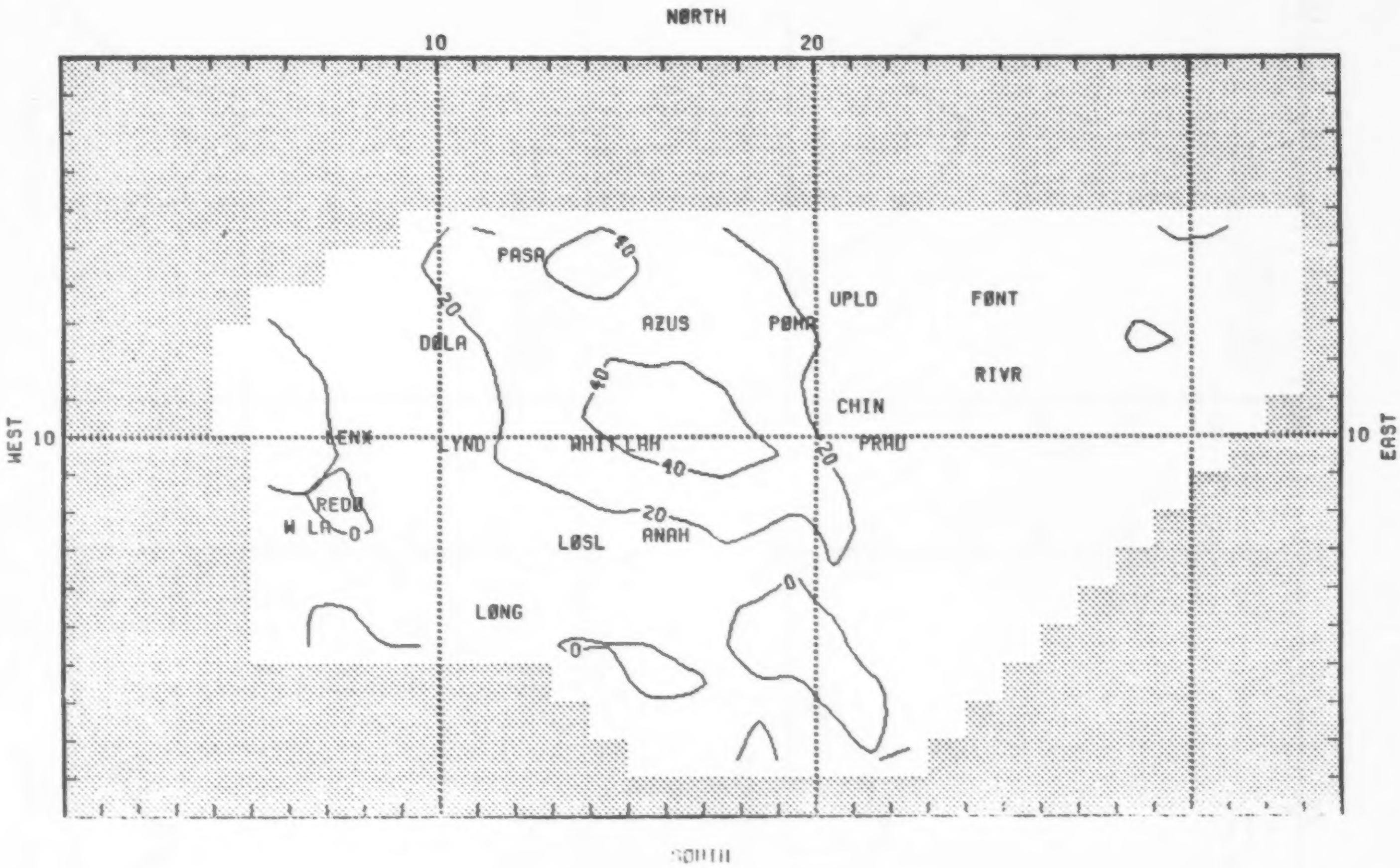

NØRTH
SØUTH
WEST
EAST
0
10
20
30
2.0
4.0
6.0
8.0
10.0
12.0
14.0

(b) Hydrocarbons (Tons)

FIGURE A-47 (Concluded)

TABLE A-20. TOTAL DAILY EMISSIONS FROM MOBILE SOURCES

Species	Nitrogen Oxides (tons of NO_2)	Reactive Hydrocarbons (tons)	Carbon Monoxide (tons)
Sensitivity Case	760.0	1,256	11,885
Base case	719.0	845	8,250
Ratio $= \frac{\text{sensitivity case}}{\text{base case}}$	1.06	1.50	1.44


NORTH
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PASA
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DOLA
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POMA
UPLD
FONT
RIVR
CHIN
PRAD
LENX
LYND
WHIT
LAH
40
40
20
20
REDO
W LA
0
LOSL
ANAH
LONG
0
0

FIGURE A-48. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 14--BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST

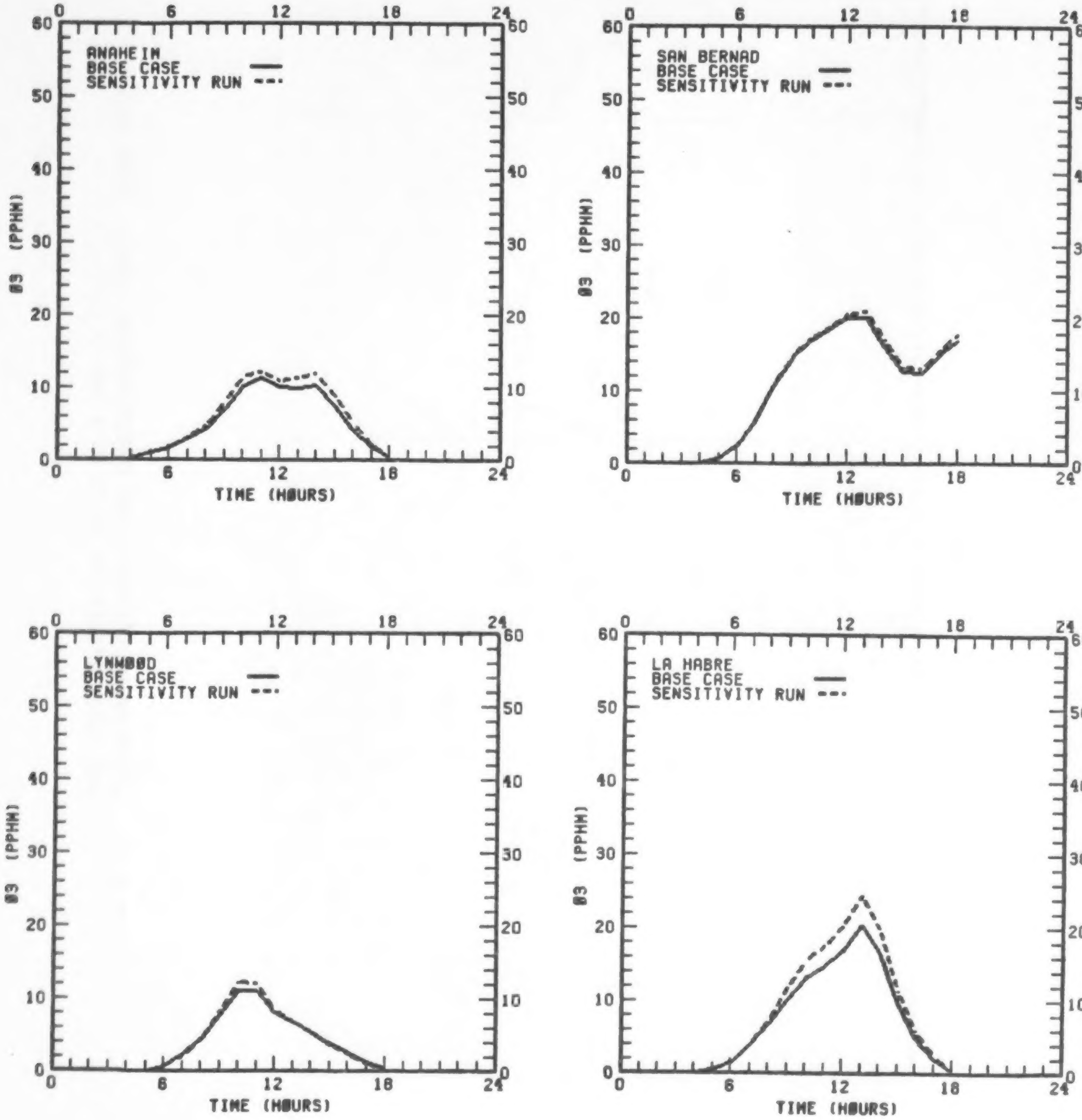


FIGURE A-49. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 14

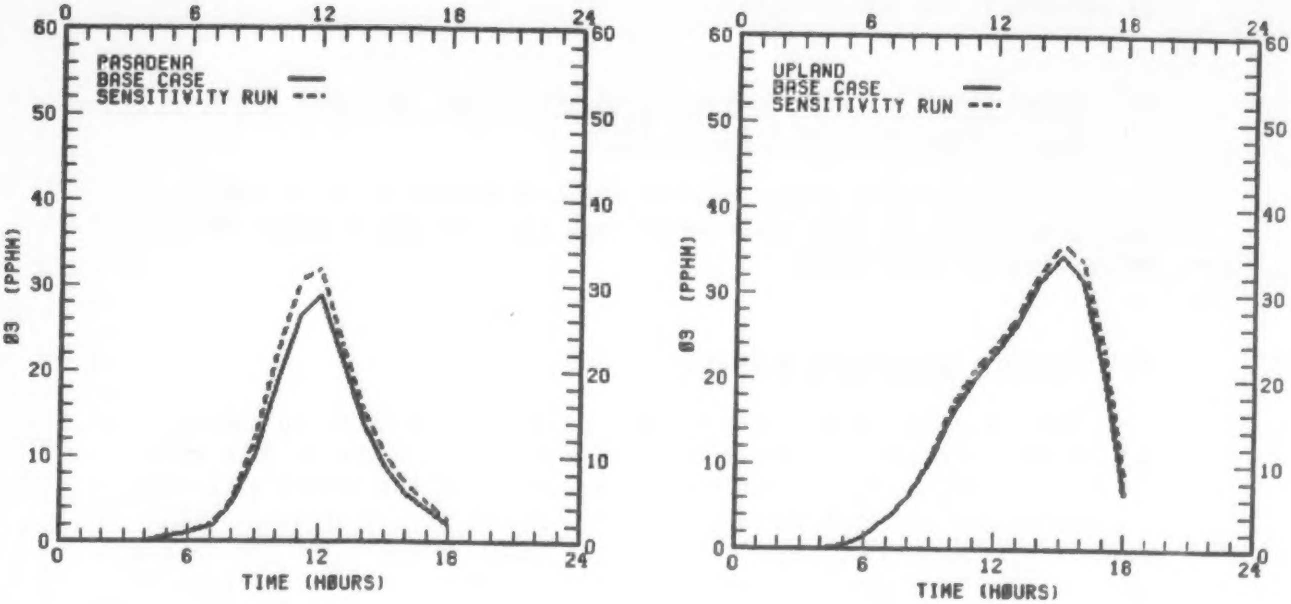


FIGURE A-49 (Concluded)

is more important than what was obtained in case 13 with the use of an older emission inventory (about 4 percent deviation is for ozone levels; 11 percent is for the dosage).

o. Model Sensitivity to Mobile Source Emissions: Estimate Based on Gas Sales--Simulation of 4 August 1975

This sensitivity study involves the same modification in mobile source emissions as that involved in case 14, with the 4 August 1975 meteorological conditions.

1) General Sensitivity Measures

Some measures of the general sensitivity of the model to mobile source emissions are presented in table A-21. As for the 26 June 1974 conditions, higher ozone levels are predicted with the sensitivity case. The deviations are as high as 16 percent for the grid statistics, 24 percent for the maximum ozone statistics, and 59 percent for the dosage, which is the most sensitive measure. The overall maximum ozone peak is not much perturbed, though it occurs at a different location (grid [11-16] instead of grid [30-16]).

The temporal correlation is high, but the spatial correlation is slightly lower (0.74 for stations with ozone levels above 12 pphm). Compared with case 14, wind velocities are larger and mixing depths are lower, which probably enhances the spatial spreading of the perturbations in the model predictions.

2) Sensitivity of Model Input Variables to Input Data

The mobile source emissions have been modified in this sensitivity case as in case 14. Thus, higher emission levels from mobile sources are considered in the sensitivity case.

3) Sensitivity of Ozone Levels to Mobile Source Emissions

Isopleths of maximum ozone deviation are shown in figure A-50. As in case 14, larger deviations in ozone levels occur in mid basin; however, the deviations are higher than in case 14 (80 ppb near Azusa and Pasadena). The perturbations affect a much larger area than was affected by the 26 June 1974 conditions. This appears clearly in the ozone profiles shown in figure A-51. For instance, the perturbations in ozone

TABLE A-21. GENERAL SENSITIVITY MEASURES--CASE 15

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	$O_3 > 12$ pphm	$O_3 > 20$ pphm	$O_3 > 12$ pphm	$O_3 > 20$ pphm
Signed deviation	0.115	0.082	0.146	0.095
Absolute deviation	0.127	0.084	0.160	0.108
Temporal correlation	0.977	0.955	0.963	0.945
Spatial correlation	0.738	0.922	0.905	0.840

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	1.139	1.033
Peak level (pphm):		
Sensitivity case	30.0	38.3
Base case	26.3	37.0
Corresponding locations:		
Sensitivity case	Pomona	11 - 16
Base case	Pomona	30 - 16

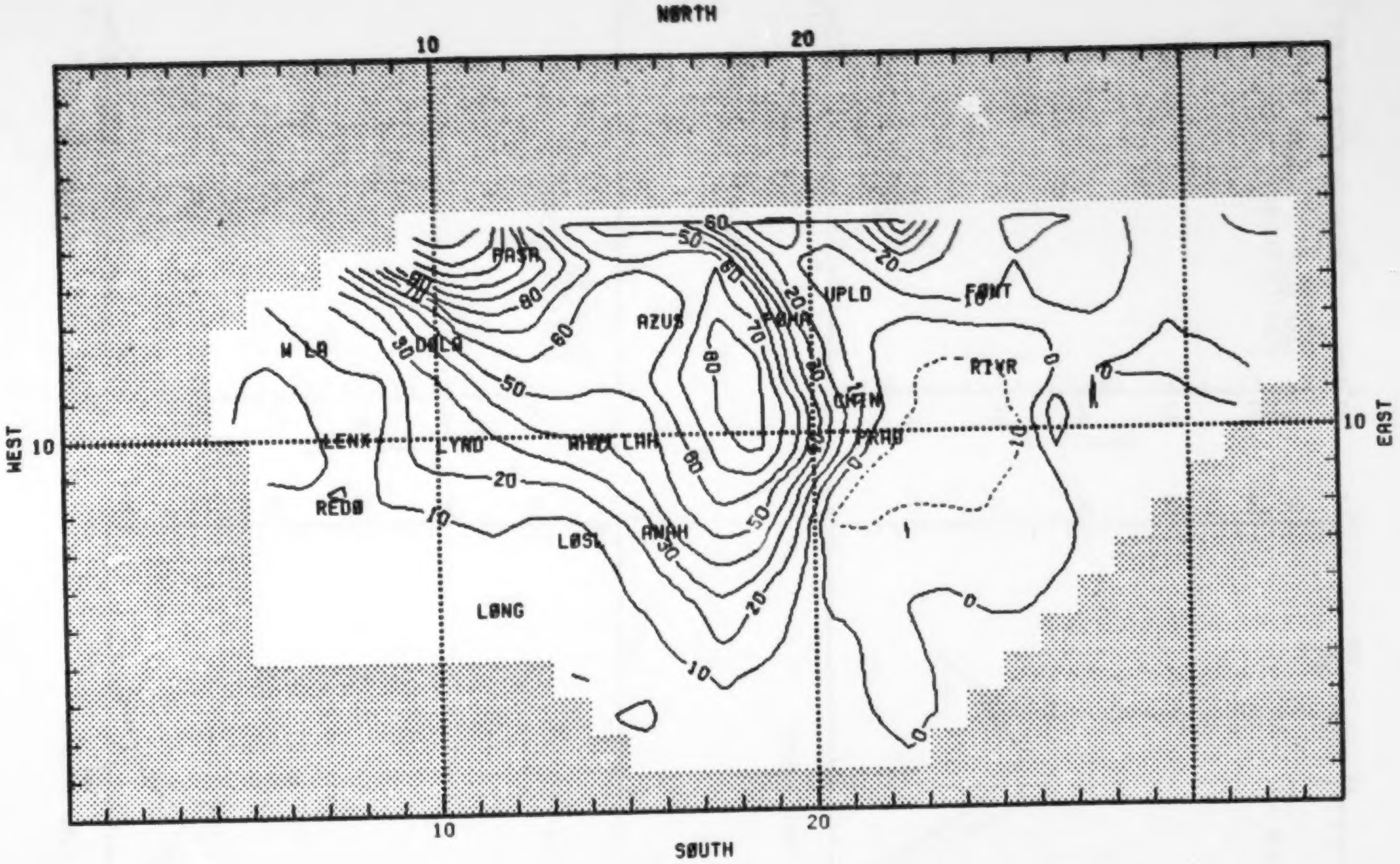
TABLE A-21 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.243	0.214
Peak time lag (hrs)	0.130	0.260

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
0.59	13,900	8,750


NORTH
SOUTH
WEST
EAST
10
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PASA
AZUS
UPLD
FONT
POMA
CHIN
RIVR
PRAD
W LA
DOLA
LENX
LYND
WHTR LAHB
REDO
LOSL
ANAH
LONG
80
70
60
50
30
20
10
0

FIGURE A-50. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS: CASE 15--BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST

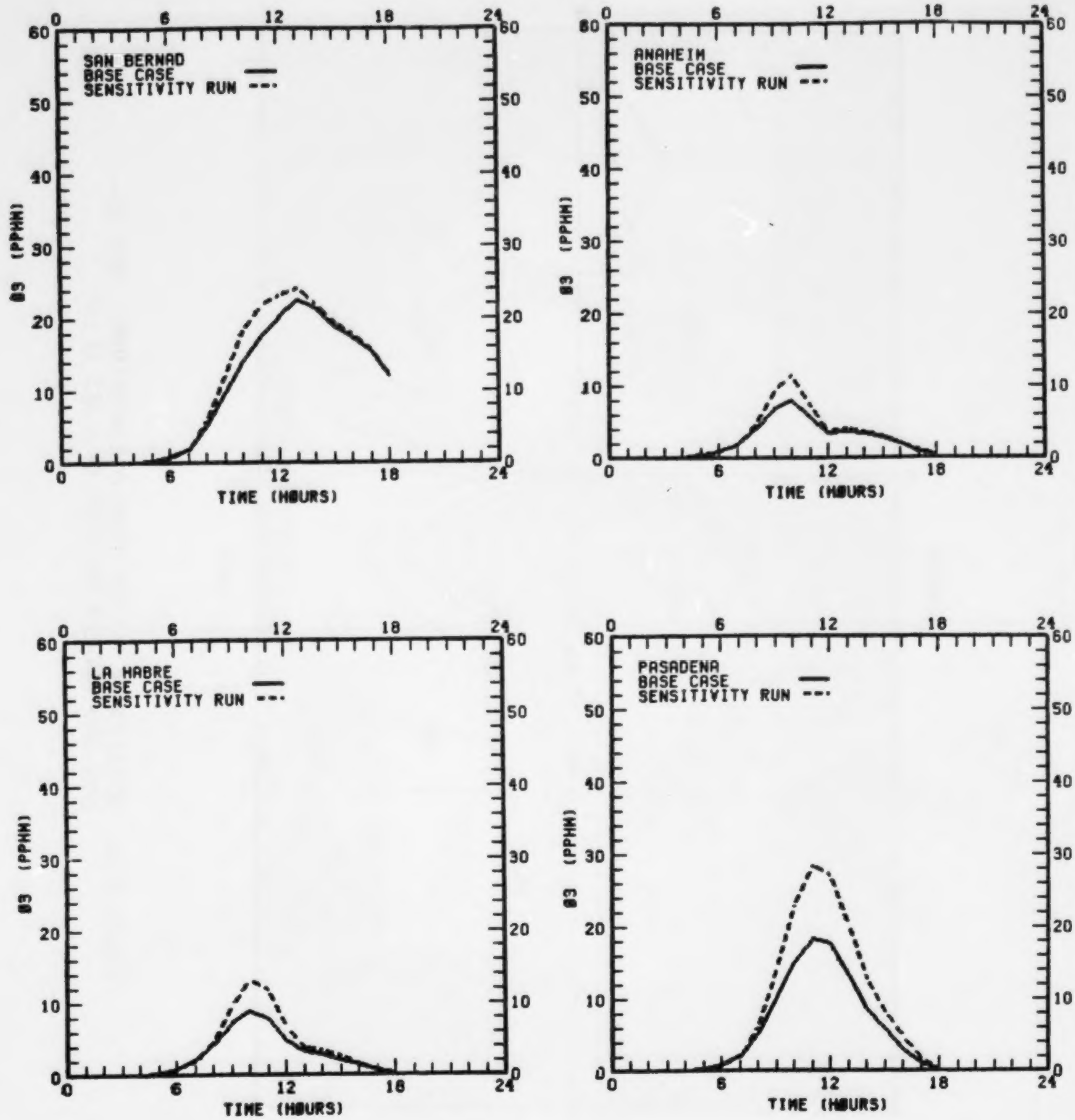


FIGURE A-51. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 15

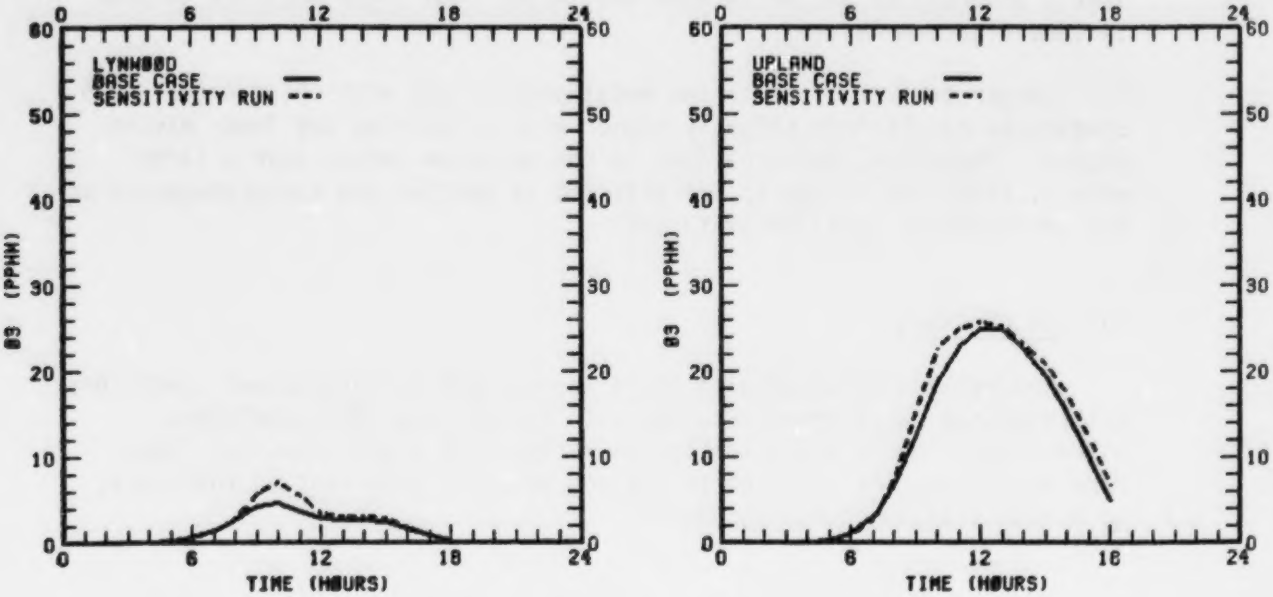


FIGURE A-51 (Concluded)

levels observed at San Bernardino are larger than those obtained in case 14 (See figure A-49).

Larger perturbations in the model predictions with the 4 August 1975 conditions result from slightly higher wind velocities and lower mixing depths. Therefore, perturbations in the emission levels have a larger effect, since the mixing volume affected is smaller and the propagation of the perturbation is slightly faster.

4) Conclusions

The results obtained with the 4 August 1975 meteorological conditions are consistent with those obtained with the 26 June 1974 conditions. Higher ozone levels are predicted as a result of higher emission levels from mobile sources. The perturbations are more important in this case, as a result of lower mixing depths.

p. Model Sensitivity to Point Source Temporal Resolution--Simulation of 26 June 1974

In this sensitivity study, temporal profiles of point source emissions have been modified. A yearly averaged emission pattern was chosen instead of the more detailed daily emission data. As a result, lower nitrogen oxides emissions were obtained for the sensitivity case.

1) General Sensitivity Measures

The overall sensitivity of the model to point source emissions is presented in table A-22. The perturbations on the ozone level predictions are small. The largest perturbation occurs with the peak level normalized difference (2.9 percent for all stations). The overall maximum ozone levels occur at the same locations and are not much perturbed (0.4 percent for the grids). The values of the temporal and spatial correlation coefficients are very high for both station and grid statistics (above 0.988).

In general, slightly higher ozone levels are obtained in the sensitivity case.

TABLE A-22. GENERAL SENSITIVITY MEASURES--CASE 16

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	$O_3 > 12$ pphm	$O_3 > 20$ pphm	$O_3 > 12$ pphm	$O_3 > 20$ pphm
Signed deviation	0.010	0.006	0.009	0.007
Absolute deviation	0.011	0.006	0.010	0.008
Temporal correlation	0.990	0.990	0.990	0.988
Spatial correlation	0.990	0.989	0.990	0.990

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	1.000	0.996
Peak level (pphm):		
Sensitivity case	35.5	38.7
Base case	35.5	38.9
Corresponding locations:		
Sensitivity case	Azusa	33 - 14
Base case	Azusa	33 - 14

TABLE A-22 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.029	0.020
Peak time lag (hrs)	0.13	0.19

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
0.013	10.125	10,000

2) Sensitivity of Model Input Variables to Input Data

Emission levels of point sources have been perturbed by averaging emissions over the year. Point sources release nitrogen oxides, sulfur dioxide, and particulates, primarily. In the present simulation, nitrogen oxides are the pollutant of interest. The averaging procedure resulted in lower nitrogen oxides emissions.

3) Sensitivity of Ozone Levels to Point Source Emissions

Isopleths of maximum ozone deviation are shown in figure A-52. Deviations are less than 10 ppb throughout the basin. Ozone profiles at seven air quality monitoring stations are presented in figure A-53. The agreement between the sensitivity case and the base case is good except at La Habra, Anaheim, and Los Alamitos. These three stations are located in areas downwind of point sources. Lower nitrogen oxides emissions lead to higher ozone levels; in the Los Angeles basin the hydrocarbon/nitrogen oxides ratio is such that decreasing nitrogen oxides concentrations increase ozone concentrations in the near downwind area.

4) Conclusions

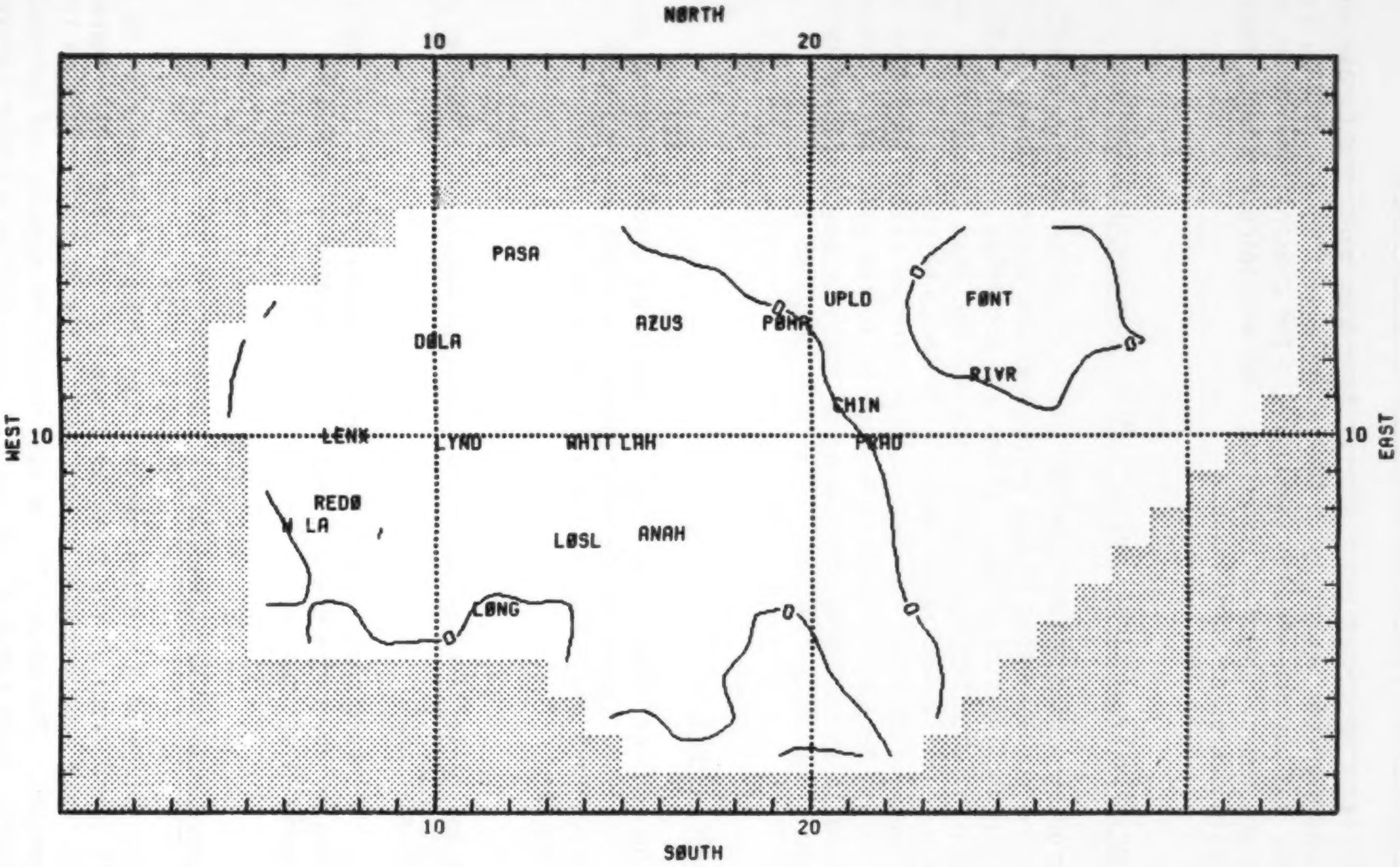
The temporal resolution of point source emissions does not appear to be an important factor in the dynamics of the urban airshed model since the effects are small and limited to areas immediately downwind of the point sources.

q. Model Sensitivity to Area Source Spatial Resolution--Simulation of 26 June 1974

In this sensitivity case, the spatial resolution of area sources has been simplified. Area sources have been allocated according to demographic distribution.

1) General Sensitivity Measures

The effect of a simpler spatial resolution of area sources on the overall sensitivity of the model is presented in table A-23. There is a general trend toward higher ozone levels. The deviations are on the order of 6 percent. The dosage is the most sensitive measure and increases by 19 percent. Both temporal and spatial correlations are high (above 0.979).


NORTH
SOUTH
WEST
EAST
10
20
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20
10
10
PASA
UPLD
FONT
AZUS
POMA
DOLA
RIVR
CHIN
LENX
LYND
WHITLAH
PRAD
REDO
W LA
LOSL
ANAH
LONG
0
0
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0
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0
0

FIGURE A-52. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 16--BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST

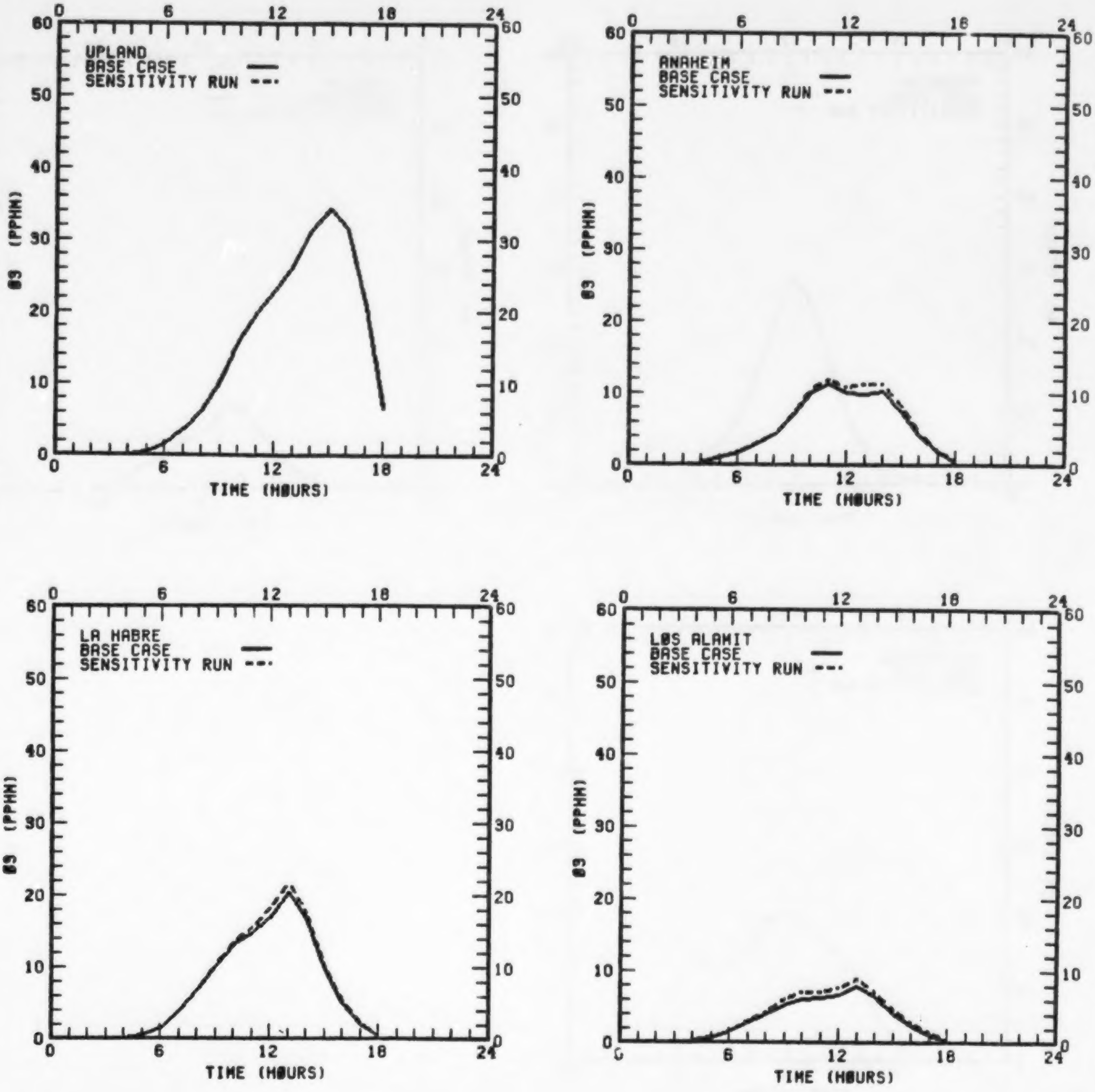


FIGURE A-53. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 16

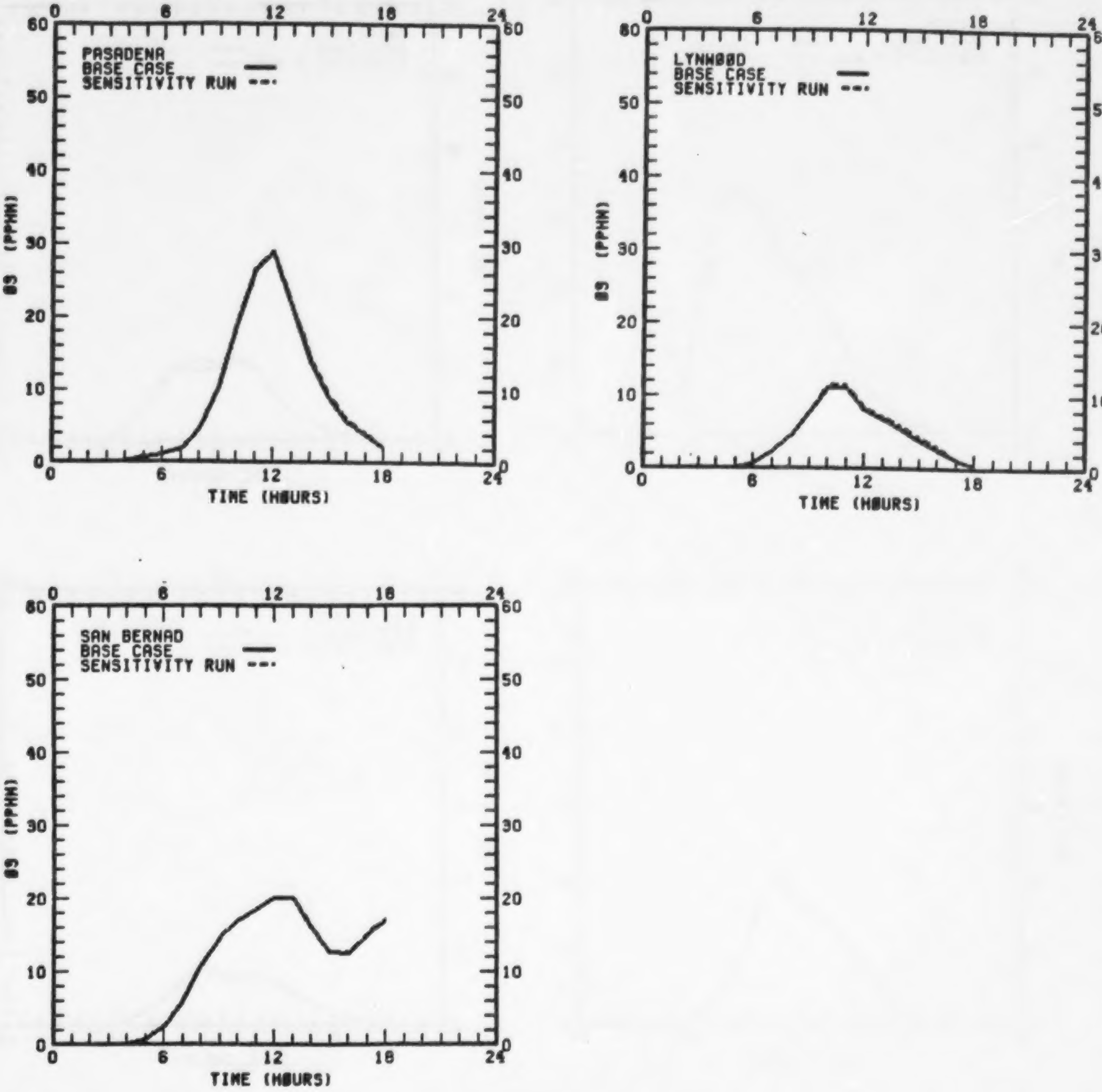


FIGURE A-53 (Concluded)

TABLE A-23. GENERAL SENSITIVITY MEASURES--CASE 17

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	$O_3 > 12$ pphm	$O_3 > 20$ pphm	$O_3 > 12$ pphm	$O_3 > 20$ pphm
Signed deviation	0.054	0.057	0.053	0.060
Absolute deviation	0.055	0.057	0.055	0.060
Temporal correlation	0.990	0.990	0.988	0.986
Spatial correlation	0.982	0.979	0.984	0.981

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	1.067	1.046
Peak level (pphm):		
Sensitivity case	37.8	40.7
Base case	35.5	38.9
Corresponding locations:		
Sensitivity case	Azusa	19 - 15
Base case	Azusa	33 - 14

TABLE A-23 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.063	0.063
Peak time lag (hrs)	0.13	0.19

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
0.193	11,925	10,000

The overall maximum ozone level occurs in a different grid, but the peak level deviation is only 4.6 percent.

2) Sensitivity of Model Input Variables to Input Data

The area source emissions have been modified. Total daily emissions of nitrogen oxides and hydrocarbons from area sources are shown in figure A-54 for this sensitivity case and the corresponding base case. The emissions of nitrogen oxides and reactive hydrocarbons are more smoothly distributed in the sensitivity case. This results from the less spatially detailed inventory procedure used in the sensitivity case.

3) Sensitivity of Ozone Levels to Area Source Spatial Resolution

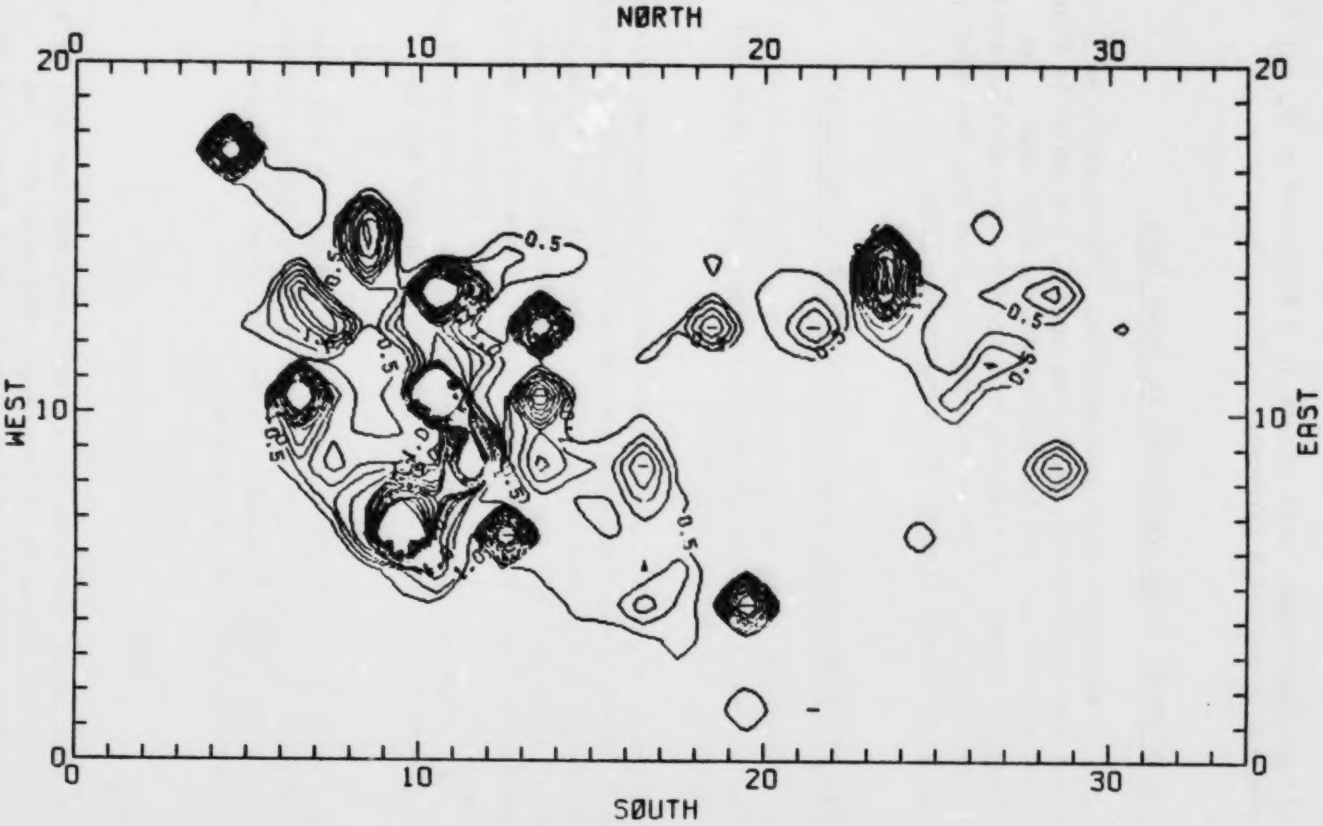
Isopleths of maximum ozone deviation are shown in figure A-55. Higher ozone levels (about 20 ppb increase) are observed in upper mid basin around Pasadena, La Habra, and Azusa.

Ozone profiles at eight air quality monitoring stations are presented in figure A-56. Ozone levels predicted by the sensitivity case are higher than those calculated in the base case. The largest deviations occur in areas downwind of important emission sources, for instance, at Azusa, Fontana, La Habra, Pasadena, and Lynwood. Further downwind the deviation in ozone predictions starts to decrease as atmospheric dispersion overcomes the initial effect of the smoother spatial distribution of the sensitivity case emissions. This effect appears at Upland and San Bernardino.

The areas along the coast are not much affected by the area source emission perturbation, since air quality predictions at those stations depend more on the initial and boundary conditions than on the emission levels (e.g., the ozone profiles at Laguna).

4) Conclusions

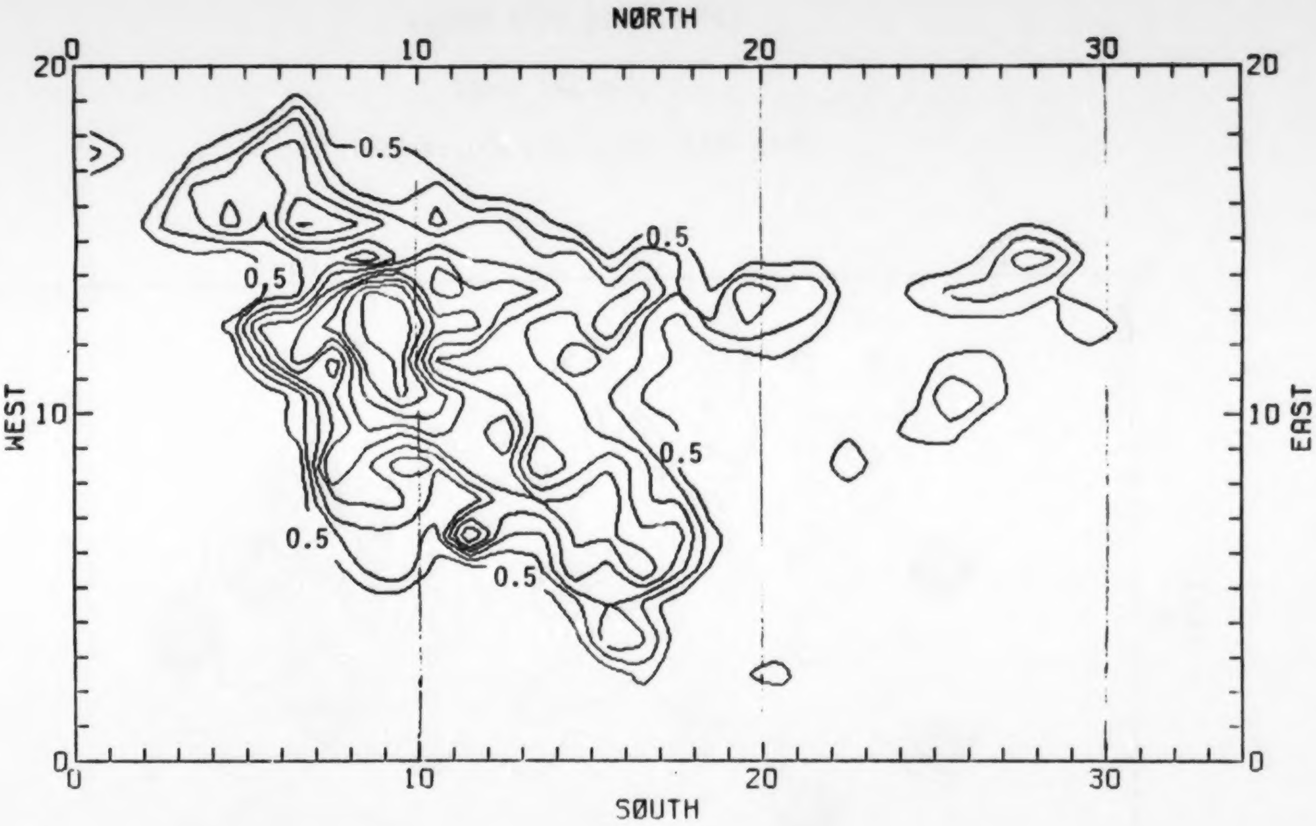
The redistribution of the area source emissions has the most affect on the areas immediately downwind of the large area sources. The perturbations in ozone levels are on the order of about 6 percent for this redistribution of emissions based on demographic distribution.


NØRTH
SØUTH
WEST
EAST
0
10
20
30
0
10
20
0.5
1.0

(a) NO_x Emissions--Base Case

(tons of NO_2 per day)

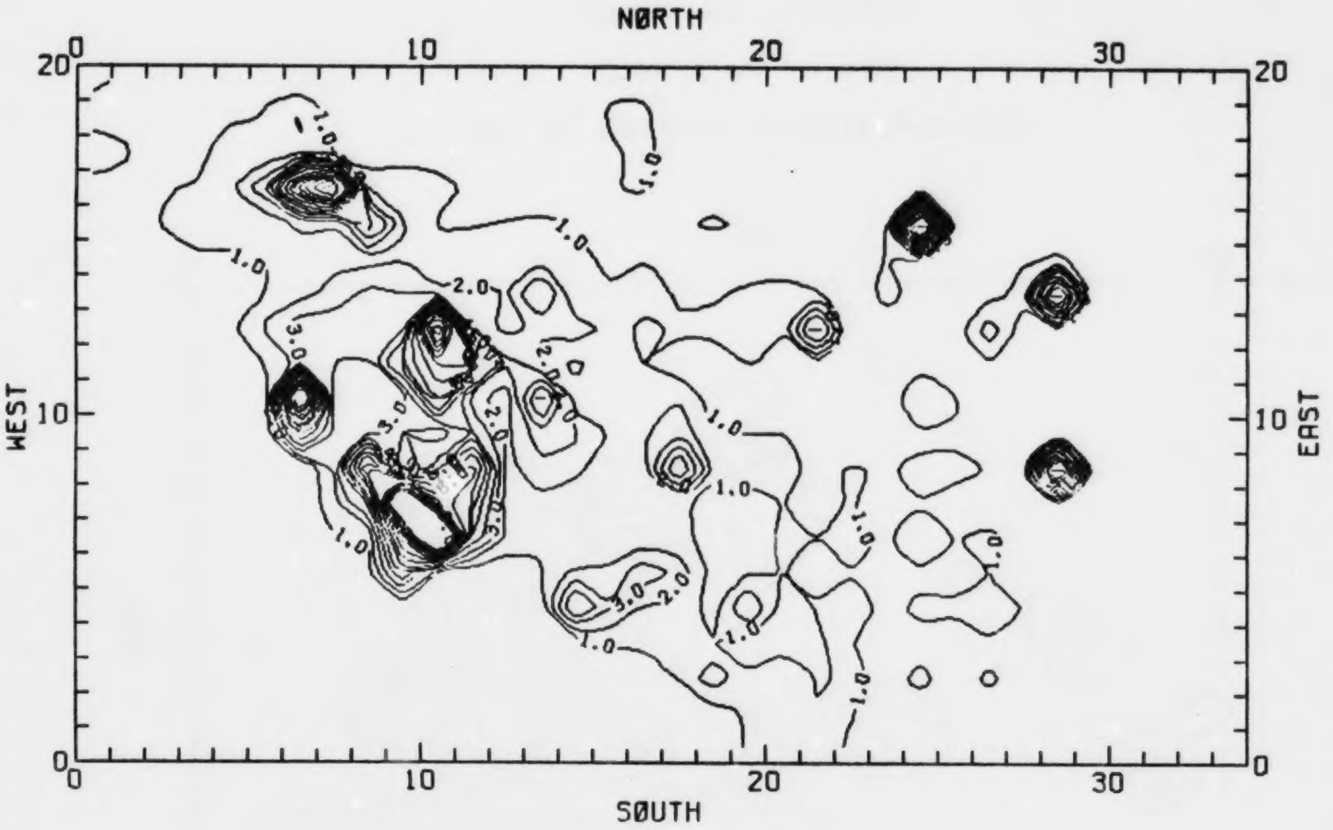
FIGURE A-54. TOTAL DAILY EMISSIONS FOR AREA SOURCES


NØRTH
SØUTH
WEST
EAST
0
10
20
30
0
10
20
0.5
0.5
0.5
0.5
0.5
0.5
0.5

(b) NO_x Emissions--Sensitivity Case 17

(tons of NO_2 per day)

FIGURE A-54 (Continued)

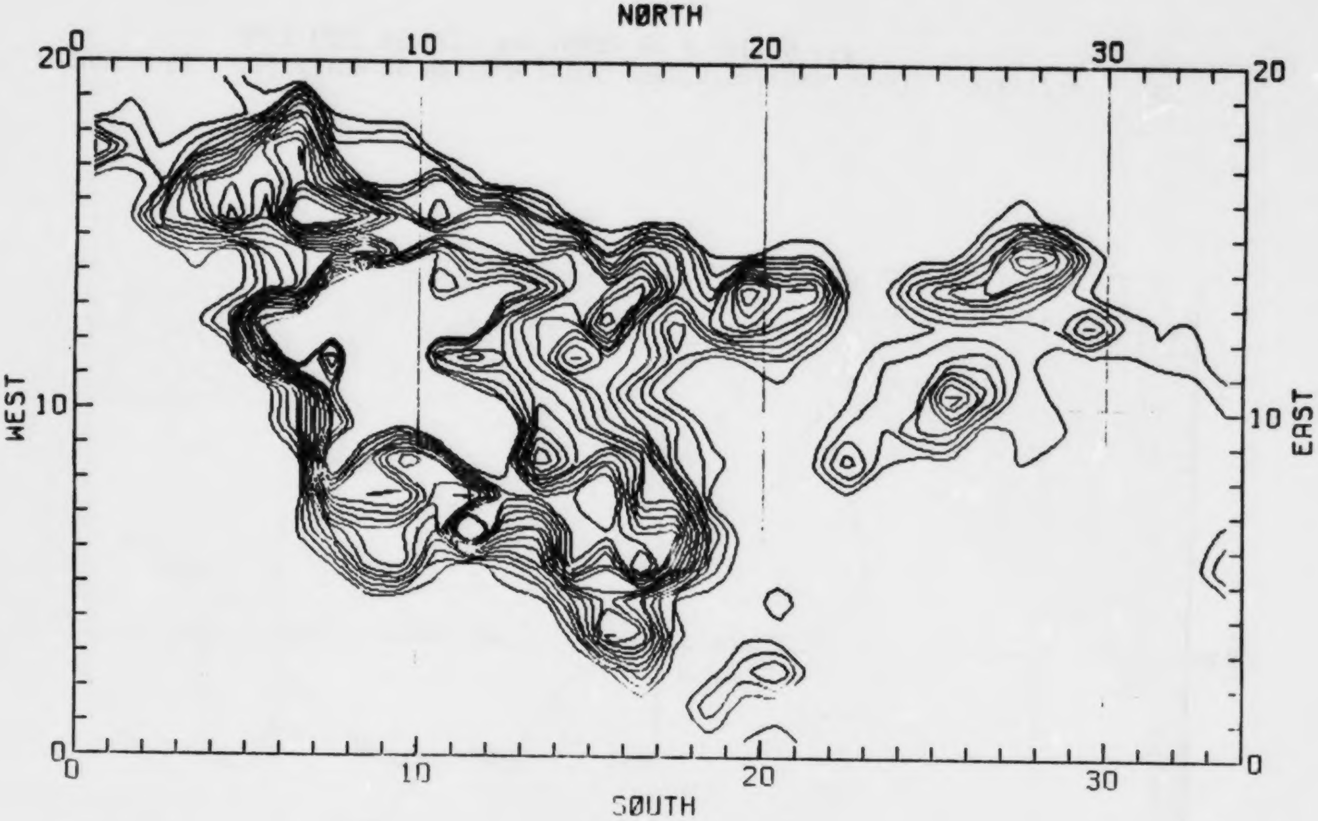


NØRTH
SØUTH
WEST
EAST
0
10
20
30
0
10
20
1.0
2.0
3.0

(c) Hydrocarbon Emissions--Base Case

(tons per day)

FIGURE A-54 (Continued)


NØRTH
SØUTH
WEST
EAST
0
10
20
30
0
10
20

(d) Hydrocarbon Emissions--Sensitivity Case 17

(tons per day)

FIGURE A-54 (Concluded)

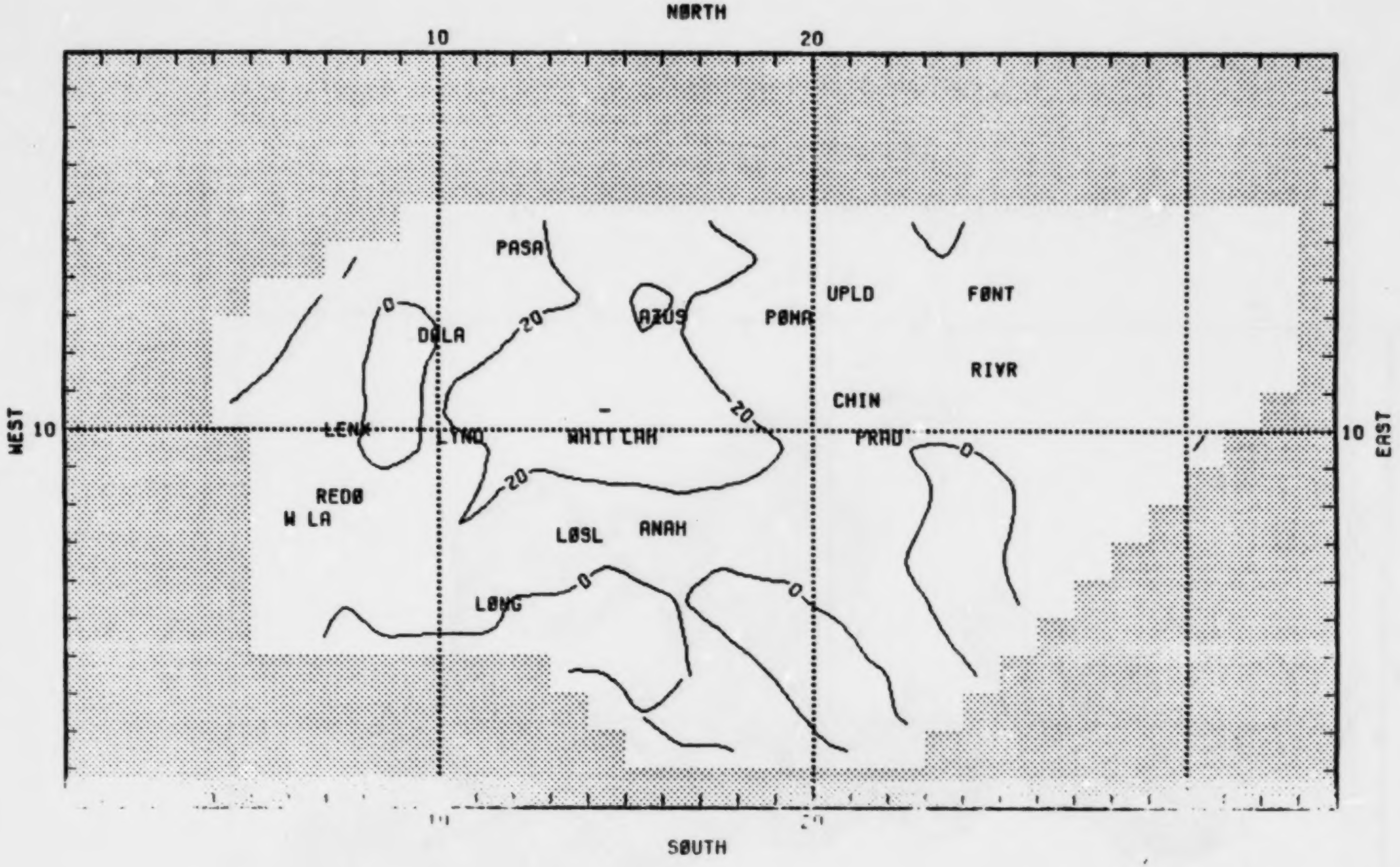

NØRTH
10
20
WEST
10
EAST
10
SØUTH
PASA
DØLA
AZUS
PØMA
UPLD
FØNT
RIVR
CHIN
LENX
LYND
WHITTLAH
PRAD
REDØ
W LA
LØSL
ANAH
LØNG
0
20

FIGURE A-55. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 17--BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST

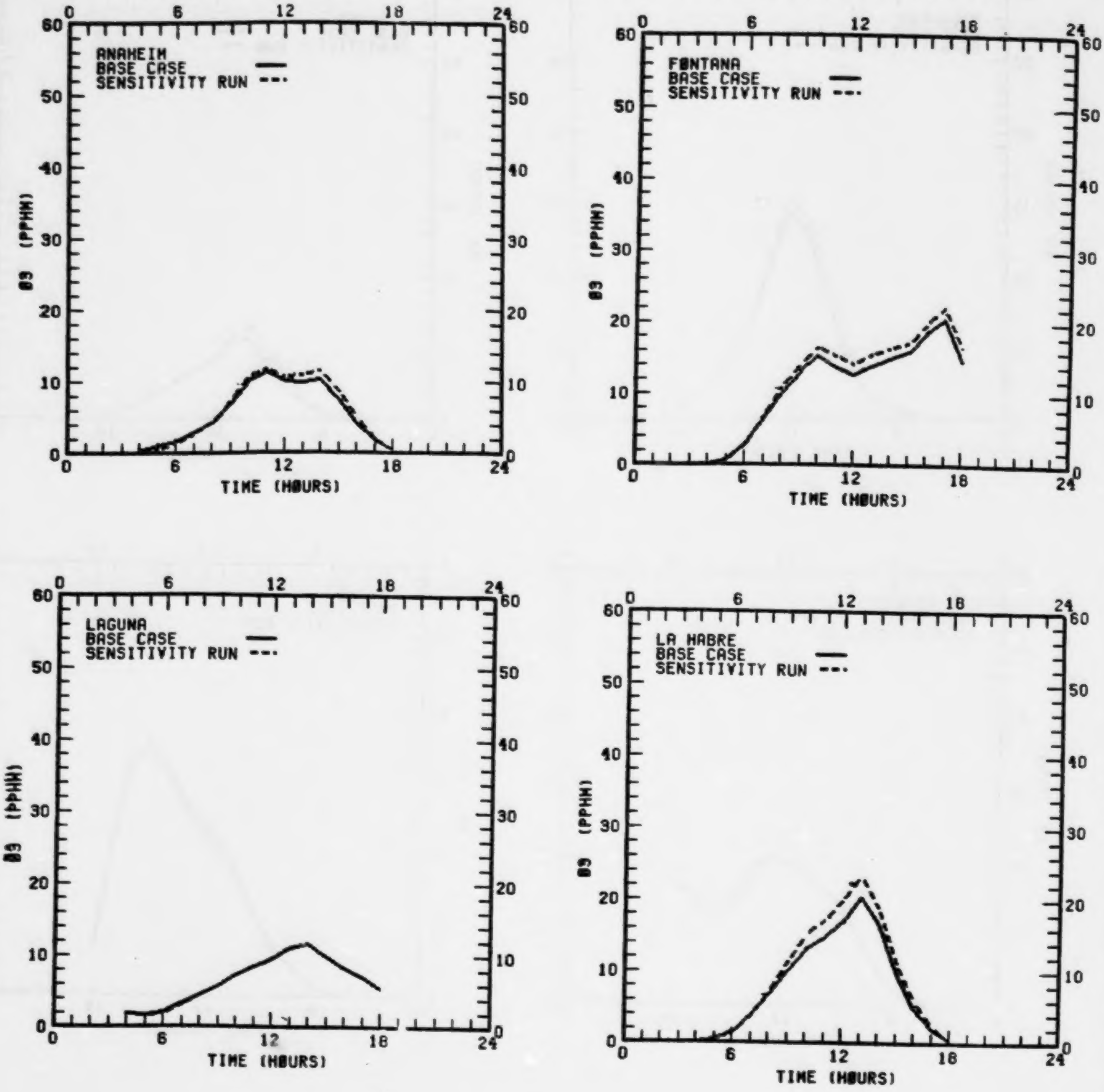


FIGURE A-56. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 17

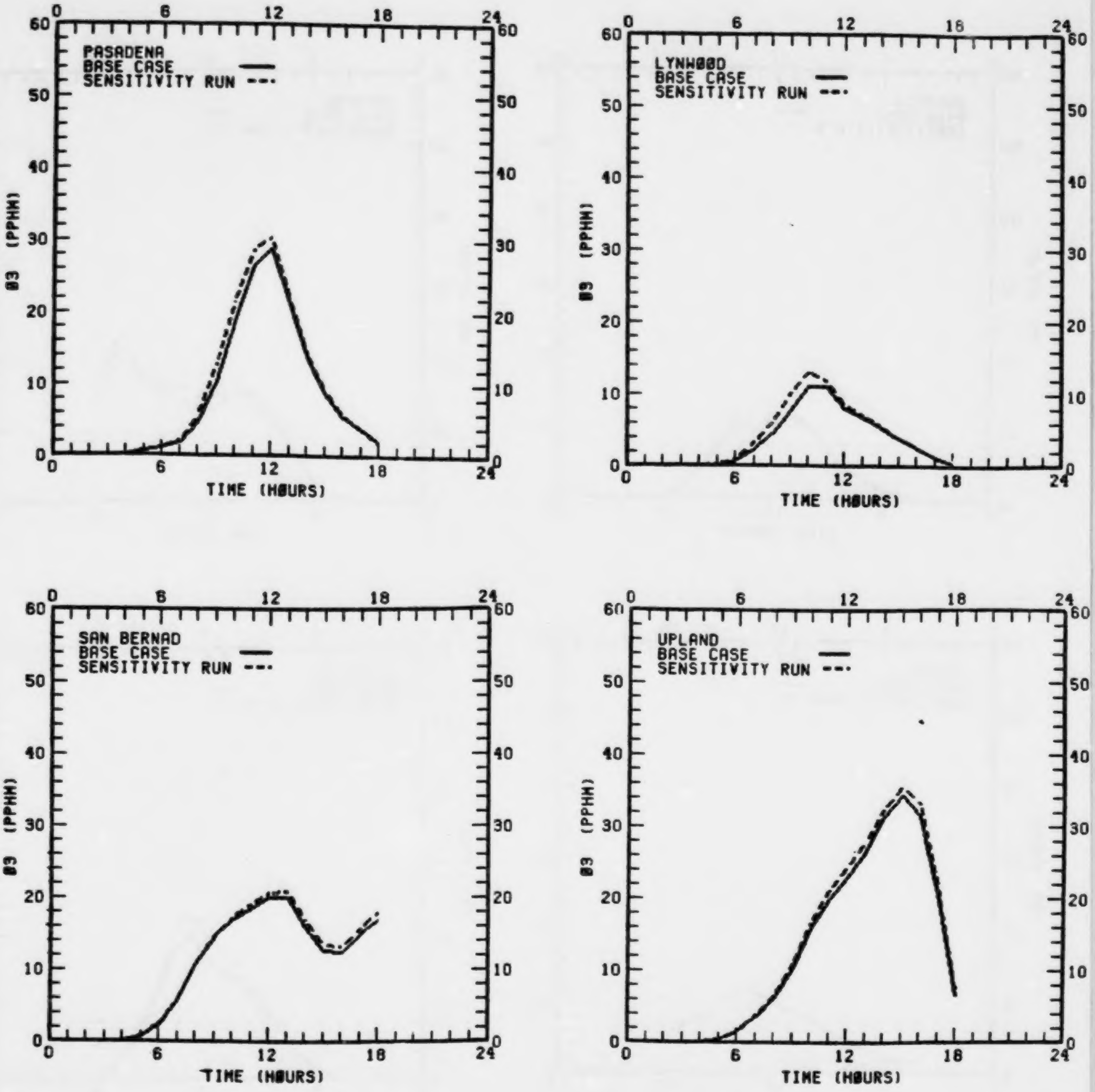


FIGURE A-56 (Concluded)

r. Model Sensitivity to Area Source Spatial Resolution--Simulation of 4 August 1975

The spatial resolution of area sources has been modified in case 18 as it was in sensitivity case 17.

1) General Sensitivity Measures

Some measures of the general sensitivity of the model are presented in table A-24. As was the case with the 26 June 1974 conditions, higher ozone levels are predicted in the sensitivity case for the 4 August 1975 conditions. Deviations from the base case are larger for this case than for case 17. This appears in the maximum ozone statistics and in the dosage, particularly.

The temporal correlation is higher than the spatial correlation. In general, deviations are on the order of 10 to 17 percent (station, grid and maximum ozone statistics).

2) Sensitivity of Model Input Variables to Input Data

The area source emissions have been modified as they were in case 17, and the total daily emissions of nitrogen oxides and hydrocarbons have been presented in figure A-54.

3) Sensitivity of Ozone Levels to Area Source Spatial Resolution

Deviations of maximum ozone levels are shown in figure A-57. Deviations as high as 70 ppb and 100 ppb occur near Azusa and Pasadena, respectively. For comparison, deviations on the order of 20 ppb in mid-basin were observed in case 17.

Ozone profiles at seven air quality monitoring stations are shown in figure A-58. A wider part of the basin is affected by the perturbation than was affected in case 17. Slightly higher wind velocities and lower mixing depths cause the enhancement of the perturbation in ozone levels. A good example of this effect is the ozone profile at Fontana, which is strongly affected in this case.

TABLE A-24. GENERAL SENSITIVITY MEASURES--CASE 18

(a) General Ozone Level Deviations

	Station Statistics		Grid Statistics	
Sensitivity Measure	O_3 > 12 pphm	O_3 > 20 pphm	O_3 > 12 pphm	O_3 > 20 pphm
Signed deviation	0.118	0.103	0.141	0.103
Absolute deviation	0.127	0.103	0.149	0.107
Temporal correlation	0.977	0.963	0.969	0.960
Spatial correlation	0.789	0.946	0.919	0.836

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	1.171	0.997
Peak level (pphm):		
Sensitivity case	30.8	36.9
Base case	26.3	37.0
Corresponding locations:		
Sensitivity case	Pomona	11 - 16
Base case	Pomona	30 - 16

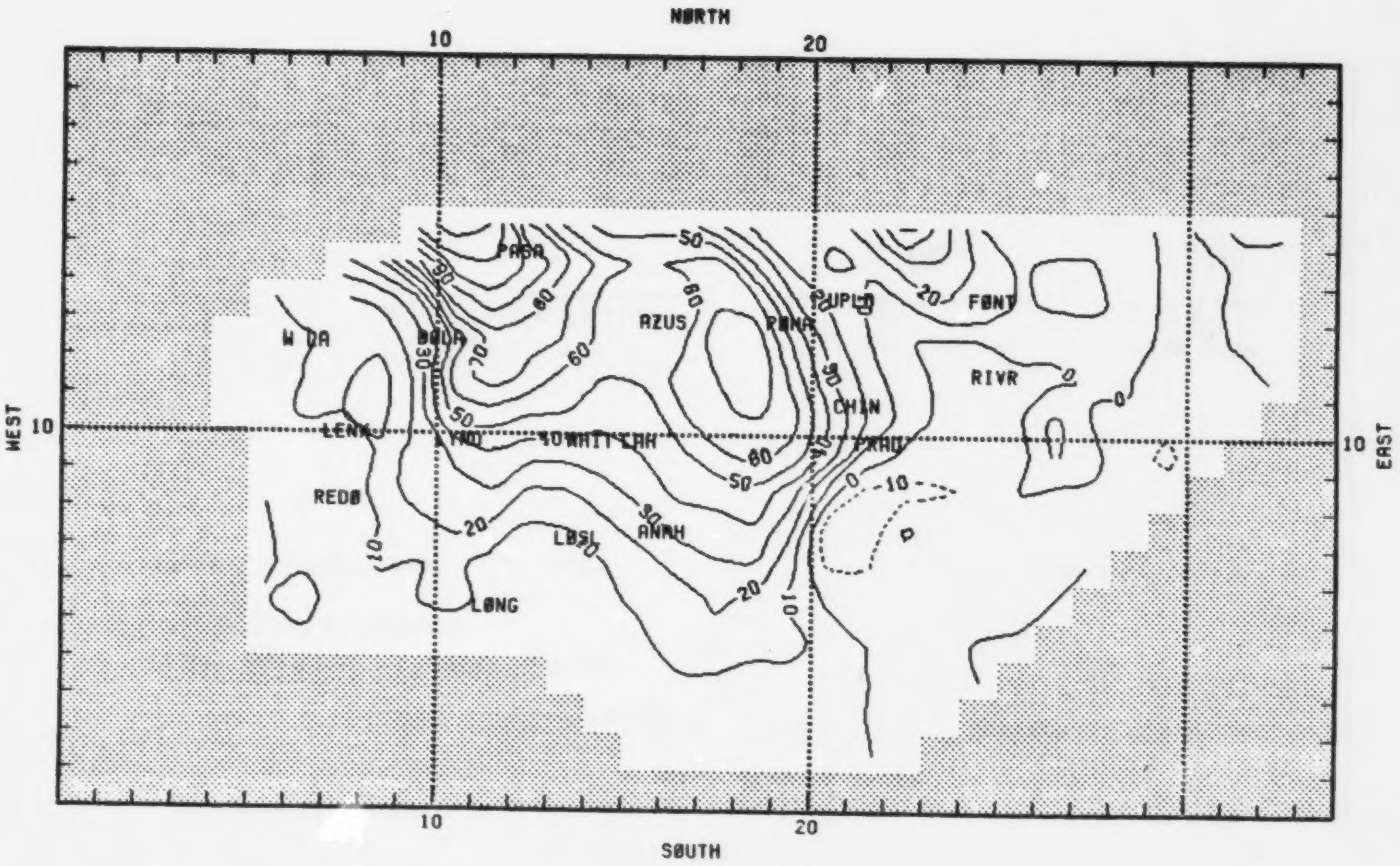
TABLE A-24 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.254	0.241
Peak time lag (hrs)	0.13	0.26

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
0.571	13,750	8,750


NORTH
SOUTH
WEST
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10
10
PASA
W DA
BURA
AZUS
POMA
UPLA
FONT
RIVR
CHIN
LENX
LYNO
WHIT
LAH
PRAD
REDO
LBSL
ANAH
LONG
50
80
60
70
30
20
10
0
-10

FIGURE A-57. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS: CASE 18--BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST

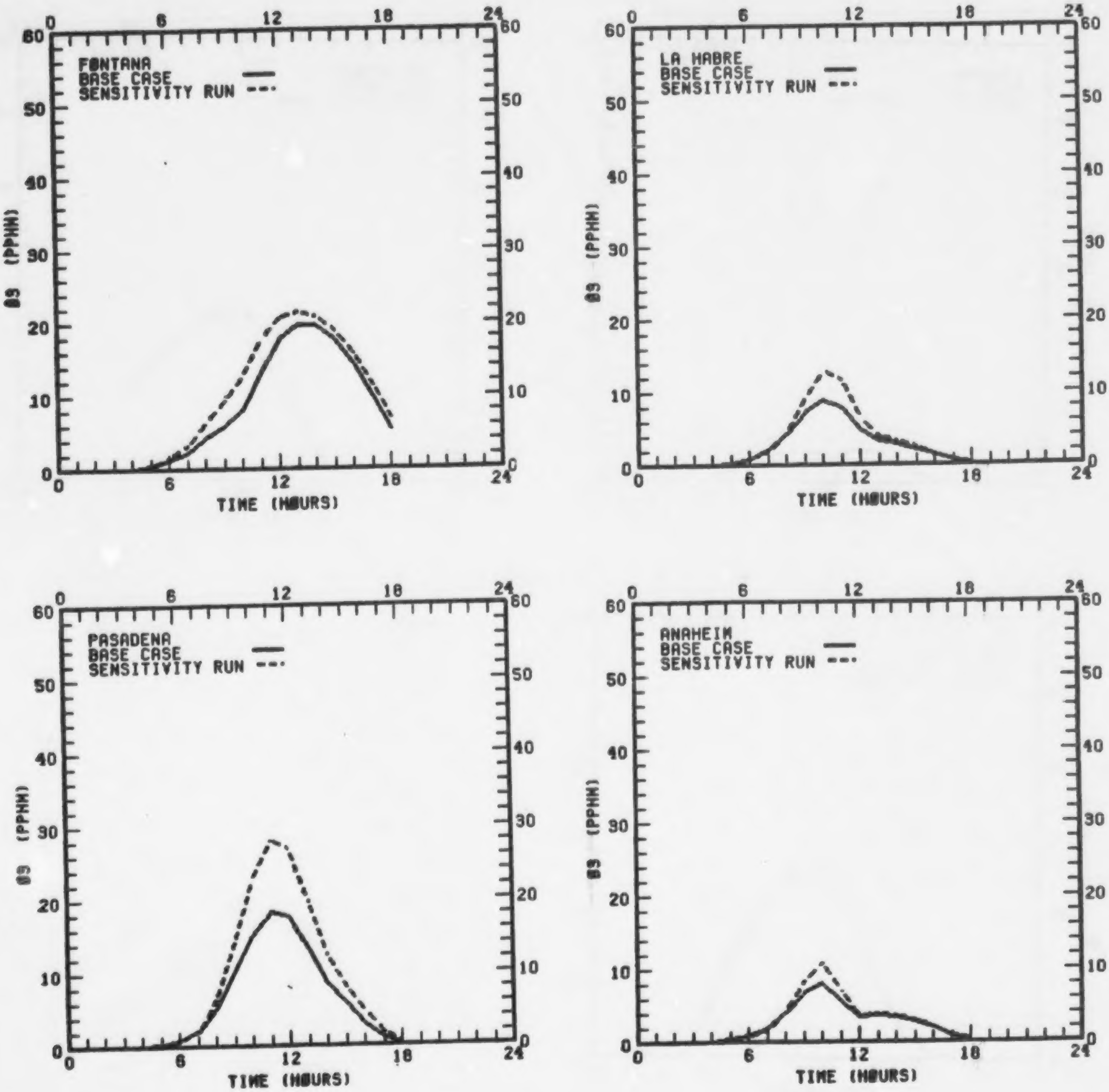


FIGURE A-58. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 18

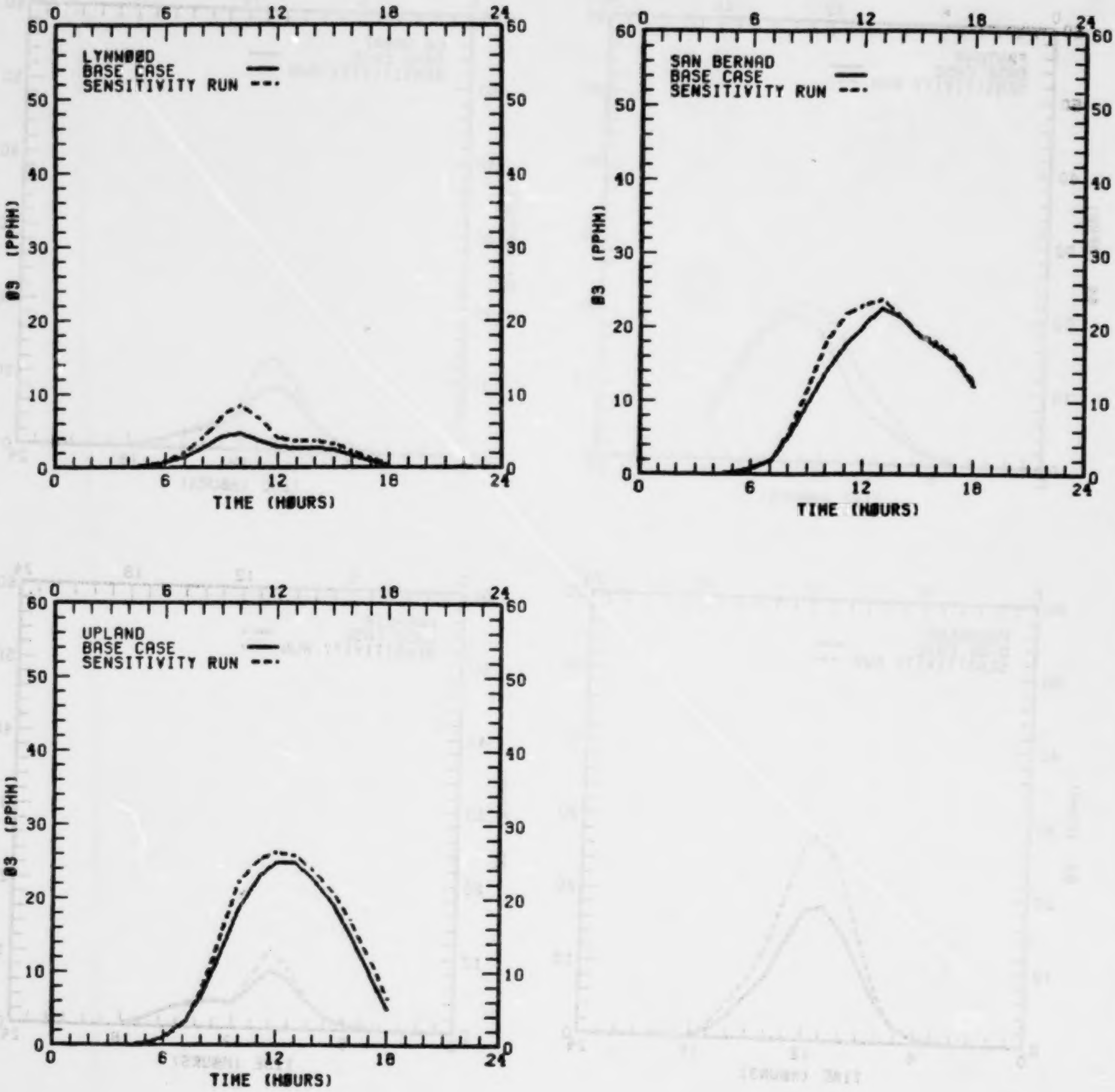


FIGURE A-58 (Concluded)

4) Conclusions

The perturbation in model predictions that results from the redistribution of the area source emissions depends on the meteorological conditions (wind velocity and mixing depth) and may be relatively high, as shown in table A-24. In general, the spatial and temporal characteristics of the model are not strongly affected, and the largest perturbation occurs in the magnitude of the ozone levels.

s. Model Sensitivity to Temporal Resolution of Area Emission Sources--Simulation of 26 June 1974

The temporal resolution of area emission sources has been simplified for this sensitivity study.

1) General Sensitivity Measures

Some measures of the overall sensitivity of the model to this perturbation in stationary sources are presented in table A-25. The temporal resolution of stationary sources does not affect the model predictions very much. In general, lower ozone levels are obtained in the sensitivity case. The deviations are on the order of 0.5 percent (station statistics) to 3 percent (dosage). The temporal and spatial correlations are high (above 0.985), and the ozone peaks occur at the same hour at all stations. The overall maximum ozone peak occurs at the same location (Azusa or grid [33-14]), and the deviation from the base case in ozone level is only 0.2 percent.

2) Sensitivity of Model Input Variables to Input Data

The only perturbation in this sensitivity case is the modification of the temporal variations of the emission term (for stationary sources) in the continuity equations.

3) Sensitivity of Ozone Levels to Temporal Resolution of Stationary Emission Sources

Isopleths of maximum ozone deviation are shown in figure A-59. Ozone profiles at six air quality monitoring stations are shown in figure A-60. No large perturbations are observed in either case.

TABLE A-25. GENERAL SENSITIVITY MEASURES--CASE 19

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	$O_3 > 12$ pphm	$O_3 > 20$ pphm	$O_3 > 12$ pphm	$O_3 > 20$ pphm
Signed deviation	-0.005	-0.006	-0.008	-0.009
Absolute deviation	0.007	0.010	0.010	0.012
Temporal correlation	0.990	0.990	0.990	0.989
Spatial correlation	0.990	0.985	0.990	0.990

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	0.988	1.002
Peak level (pphm):		
Sensitivity case	35.0	38.9
Base case	35.5	38.9
Corresponding locations:		
Sensitivity case	Azusa	33 - 14
Base case	Azusa	33 - 14

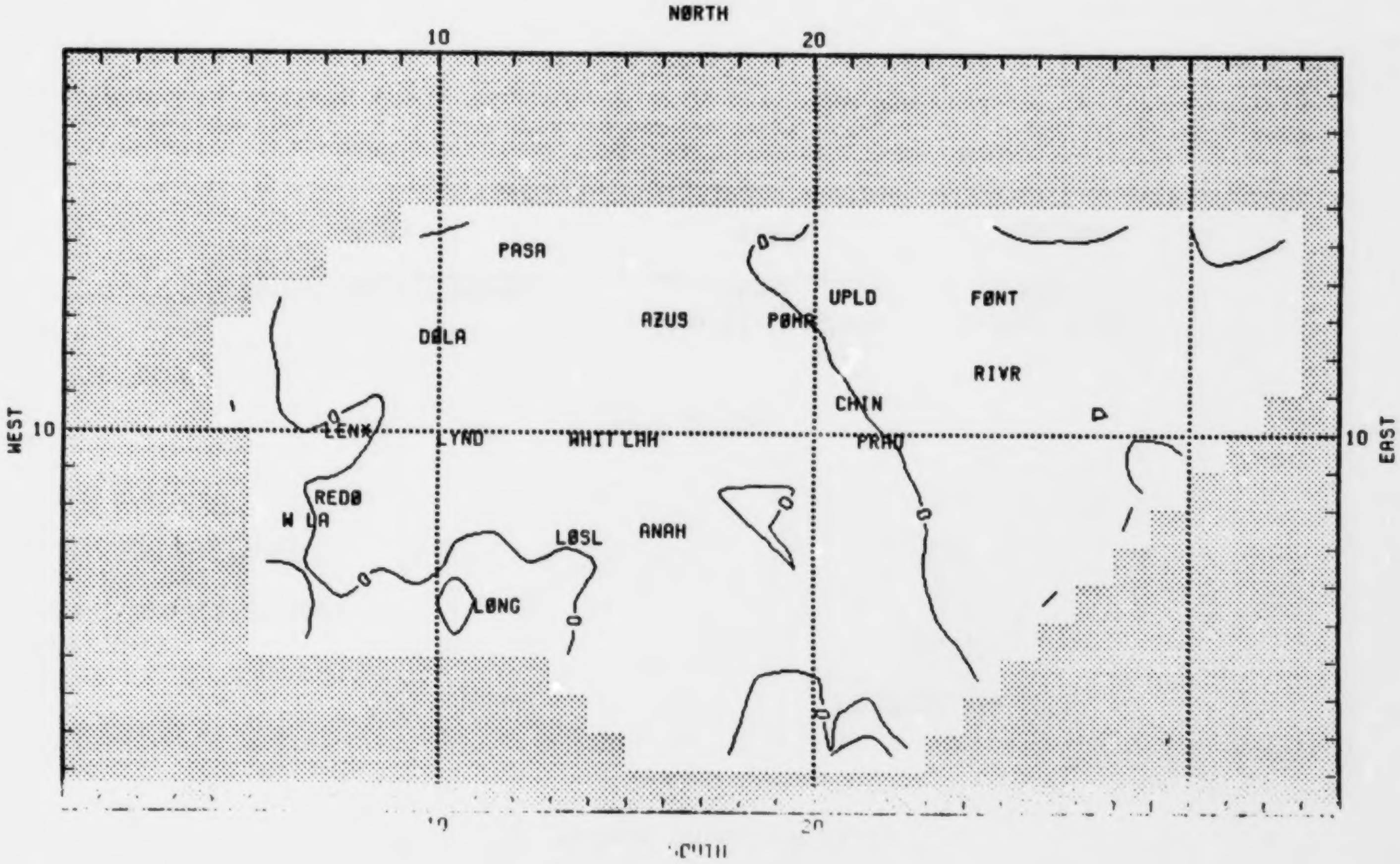
TABLE A-25 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.008	0.011
Peak time lag (hrs)	0.0	0.0

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
-0.03	9,700	10,000


NORTH
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20
WEST
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EAST
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SOUTH
10
20
PASA
UPLD
FONT
DOLA
AZUS
POMA
RIVR
CHIN
LENX
LYND
WHITLAH
PRAD
REDO
W LA
LOSL
ANAH
LONG
0

FIGURE A-59. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 19--BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST

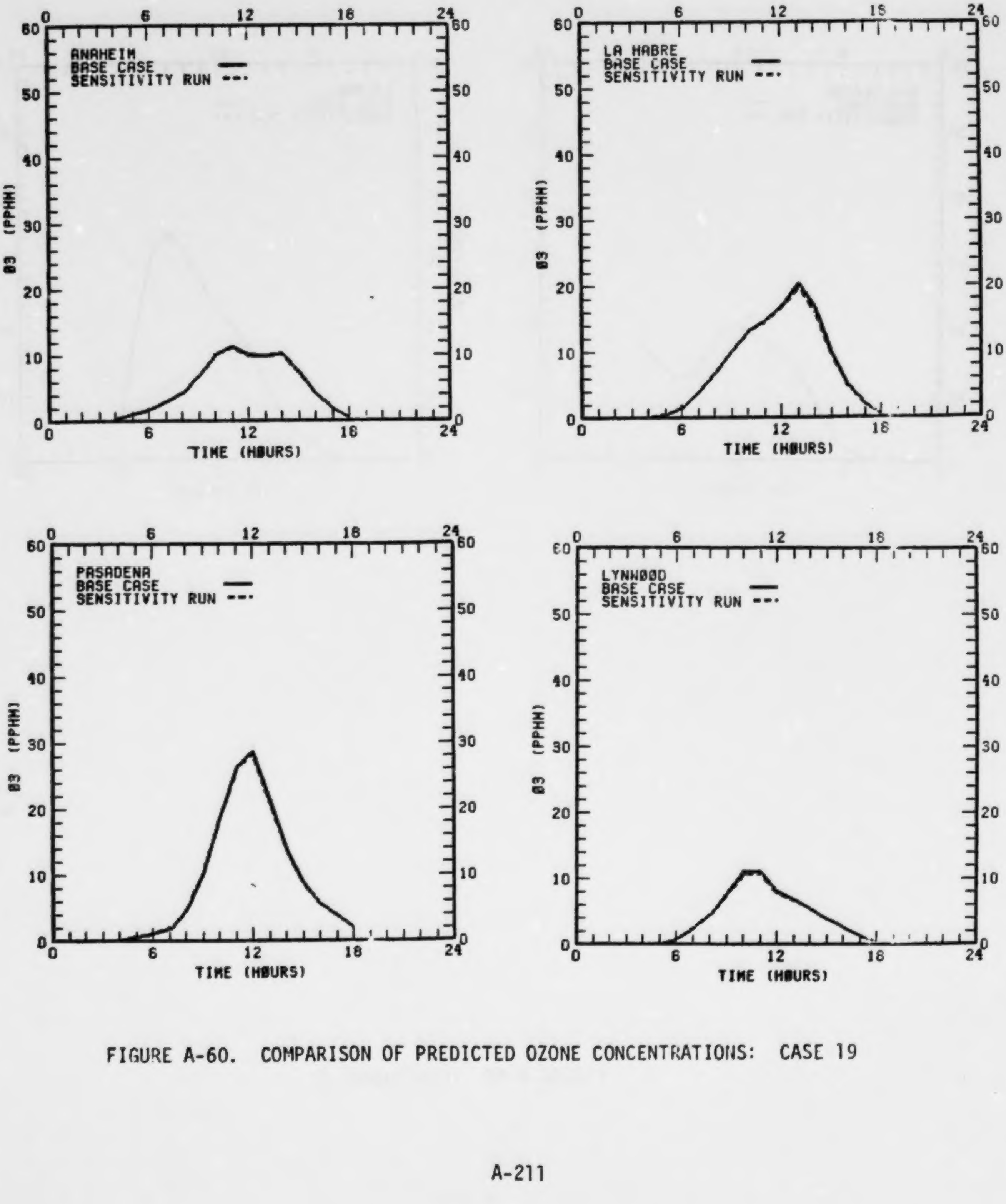


FIGURE A-60. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 19

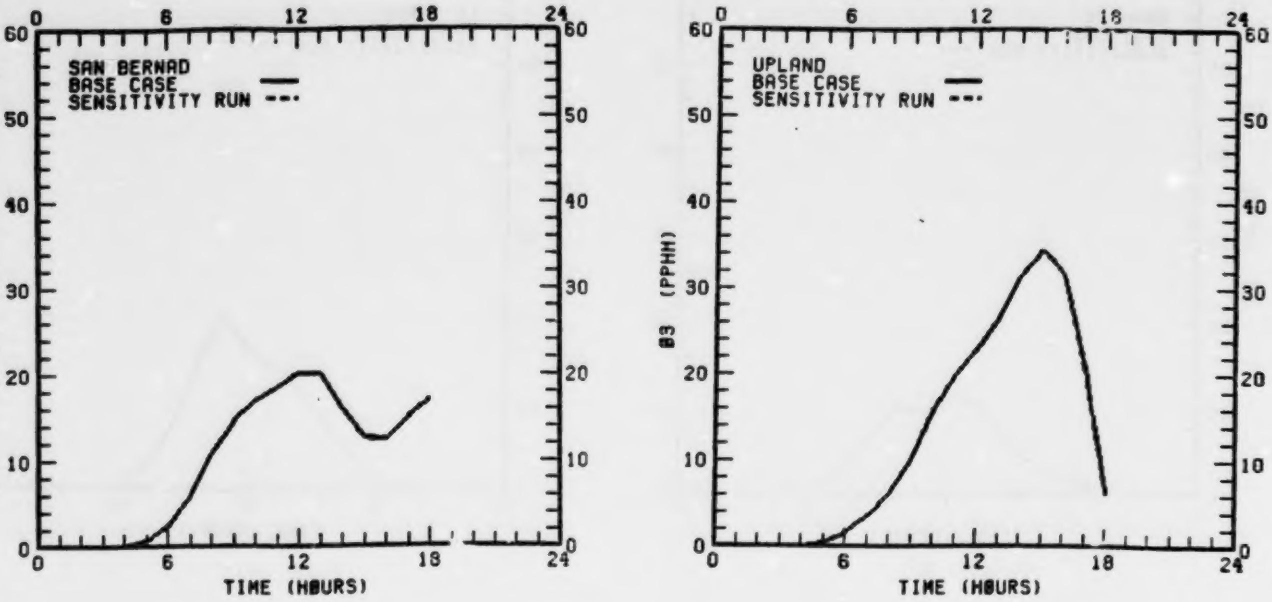


FIGURE A-60 (Concluded)

4) Conclusions

The temporal resolution of emission sources does not appear to be a parameter of major importance for the urban airshed model, since the sensitivity measures do not show any large perturbation.

t. Model Sensitivity to Grid Size--Simulation of 26 June 1974

In this sensitivity study the structure of the urban airshed model was modified. A grid size of (10 x 10) km^2 was used instead of the (5 x 5) km^2 grid of the base case.

1) General Sensitivity Measures

Some measures of the general sensitivity of the model to the grid size are presented in table A-26. The deviations in ozone levels are larger for lower ozone concentrations. There is an increase of low ozone levels (e.g., statistics for ozone levels above 12 pphm) and a decrease of high ozone levels (e.g., statistics for ozone levels above 20 pphm). This is clearly the result of averaging over a larger grid size.

The temporal correlation is high (above 0.848), since the temporal properties of the model input variables have not been perturbed. However, the spatial structure of the model has been modified, and this appears in the lower spatial correlation.

The dosage is very much affected by this perturbation, because this measure is based on the number of grids with ozone levels above 20 pphm, and a larger area is computed for the sensitivity case as a result of the larger grid size.

2) Sensitivity of Model Input Variables to Input Data

A larger grid size affects the model input and output variables (meteorological variables, emissions, and concentrations), since they are averaged over a larger area. The spatial resolution of pollutant emissions, for instance, will be less accurate, and this will affect the model predictions.

TABLE A-26. GENERAL SENSITIVITY MEASURES--CASE 20

(a) General Ozone Level Deviations

	Station Statistics		Grid Statistics	
Sensitivity Measure	$O_3 > 12$ pphm	$O_3 > 20$ pphm	$O_3 > 12$ pphm	$O_3 > 20$ pphm
Signed deviation	0.148	-0.037	0.100	-0.053
Absolute deviation	0.193	0.087	0.200	0.150
Temporal correlation	0.848	0.982	0.831	0.889
Spatial correlation	0.634	0.721	0.397	0.115

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	0.909	0.854
Peak level (pphm):		
Sensitivity case	32.2	33.2
Base case	35.5	38.9
Corresponding locations:		
Sensitivity case	Pomona	20 - 14
Base case	Azusa	33 - 14

TABLE A-26 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.155	0.112
Peak time lag (hrs)	0.545	0.750

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
0.60	16,000	10,000

3) Sensitivity of Ozone Levels to Grid Size

Isopleths of maximum ozone deviations are shown in figure A-61, and ozone profiles at eight air quality monitoring stations are presented in figure A-62.

In general, ozone profiles are smoother in the sensitivity case as a result of averaging of the variables and parameters over larger grid cells. The timing of the ozone peak is not much perturbed, except for cases where the smoothing process affects the ozone profiles notably, as at Fontana and Riverside.

The averaging of model features induces a trend toward averaging of ozone concentrations. Higher ozone levels are lower in the sensitivity case (e.g., Upland); stations with low ozone levels show higher concentrations in the sensitivity case (e.g., Anaheim). Ultimately, a box model would give an average common concentration at all stations.

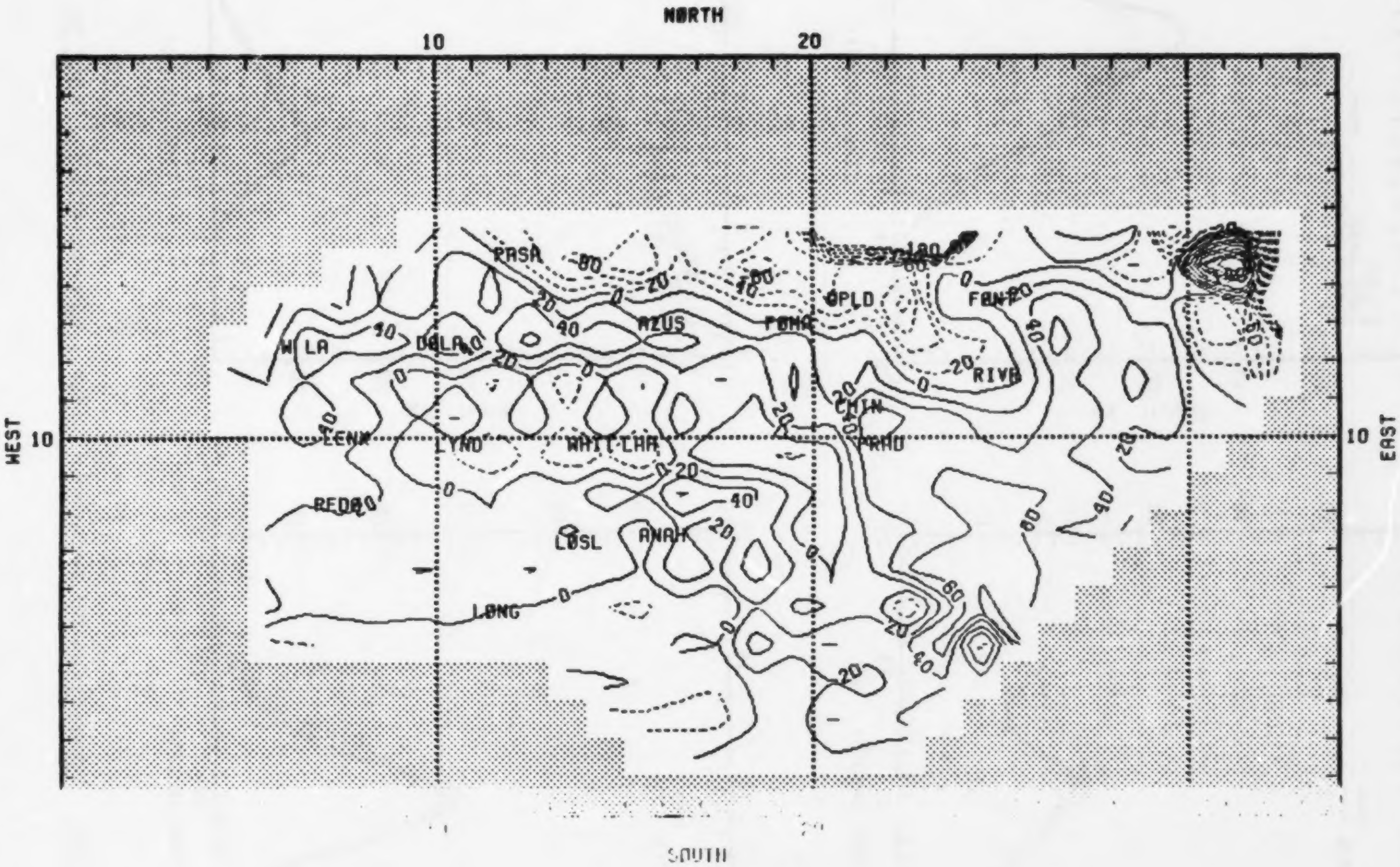
In the base case, there was a systematic bias toward underestimation of ozone levels. Since a larger grid cell leads to higher ozone levels in most areas of the basin, the model performance appears to be better with a larger grid cell. This appears in figure A-63, where ozone predictions at 4 stations are compared with atmospheric data. A similar result was obtained in an earlier study where the grid size was increased from (2 x 2) miles^2 to (4 x 4) miles^2 (S. D. Reynolds et al., 1979). However, the better prediction that is obtained with a larger grid size is coincidental, and one must consider the sensitivity of the model with respect to the base case.

4) Conclusions

The Los Angeles airshed model appears to be fairly sensitive to the grid size. The nature of the emission field and atmospheric dynamics affects the sensitivity of the model. For instance, one would expect the model to be less sensitive with a smoother emission field and important atmospheric mixing. It would be of interest to study the sensitivity of the model to the grid size for different grid sizes and urban airsheds.

u. Model Sensitivity to Grid Vertical Resolution (Two Grid Layers)--Simulation of 26 June 1974

The number of grid cell layers has been reduced in this study from four to two. The mixing depth is located between the first and second layers.


NORTH
SOUTH
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RHO
LENX
LYND
WHIT
LHB
REDO
LBSL
ANAH
LONG
0
20
40
60
80
100

FIGURE A-61. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 20--BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST

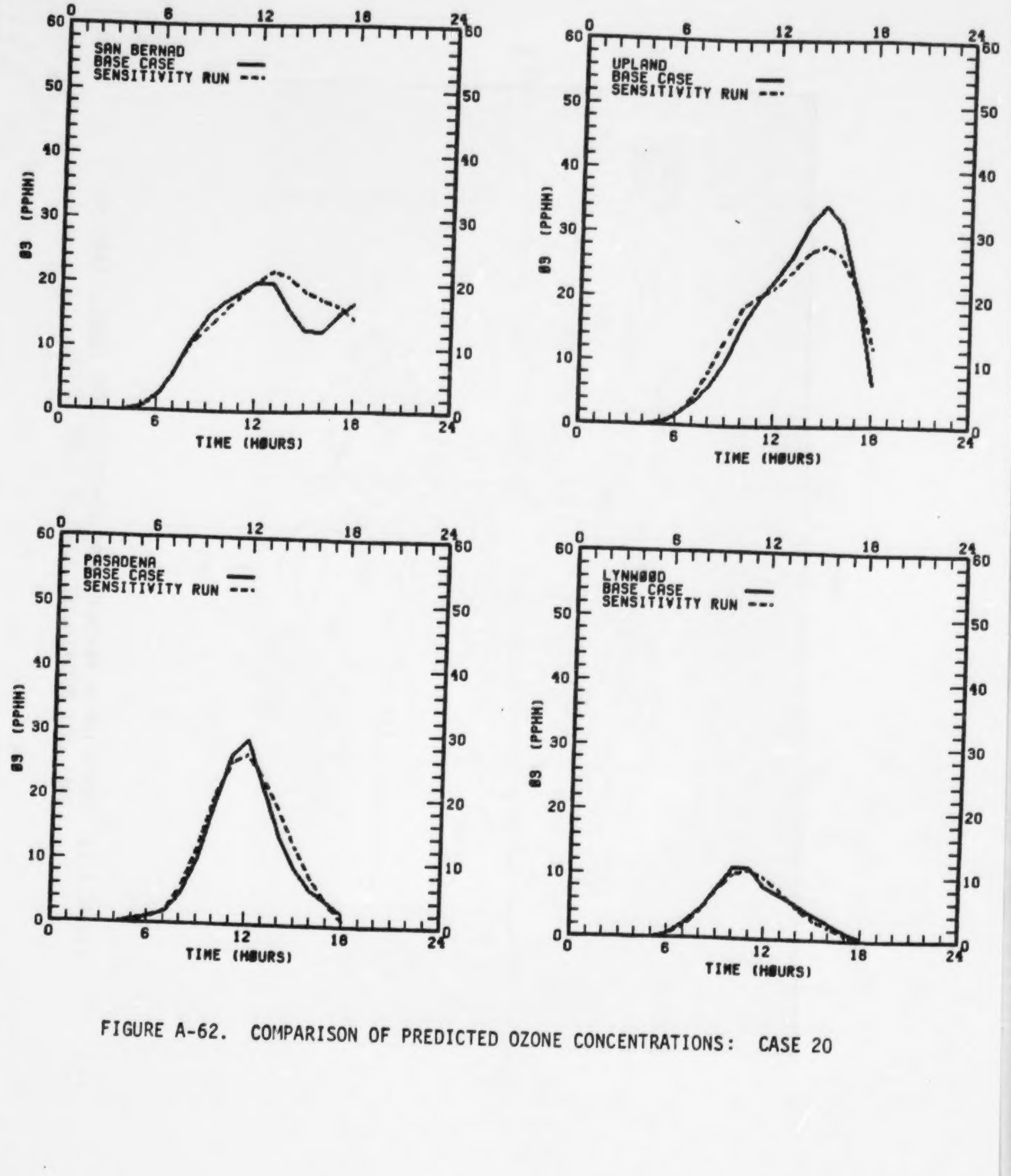

FIGURE A-62. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 20

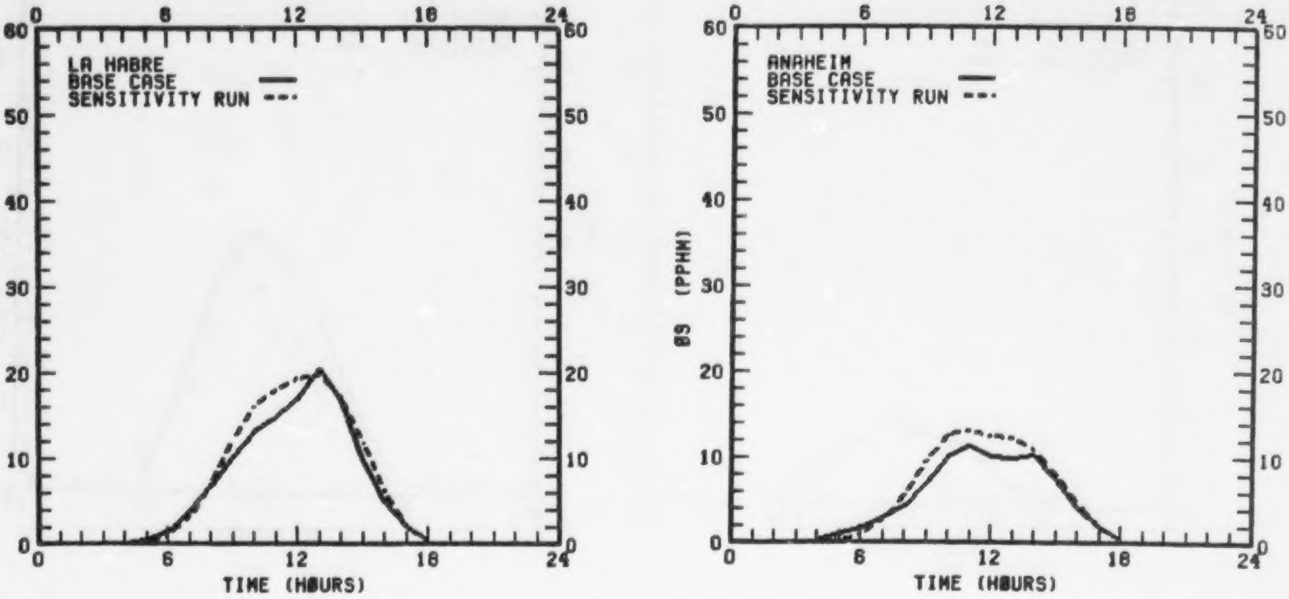

FIGURE A-62 (Concluded)

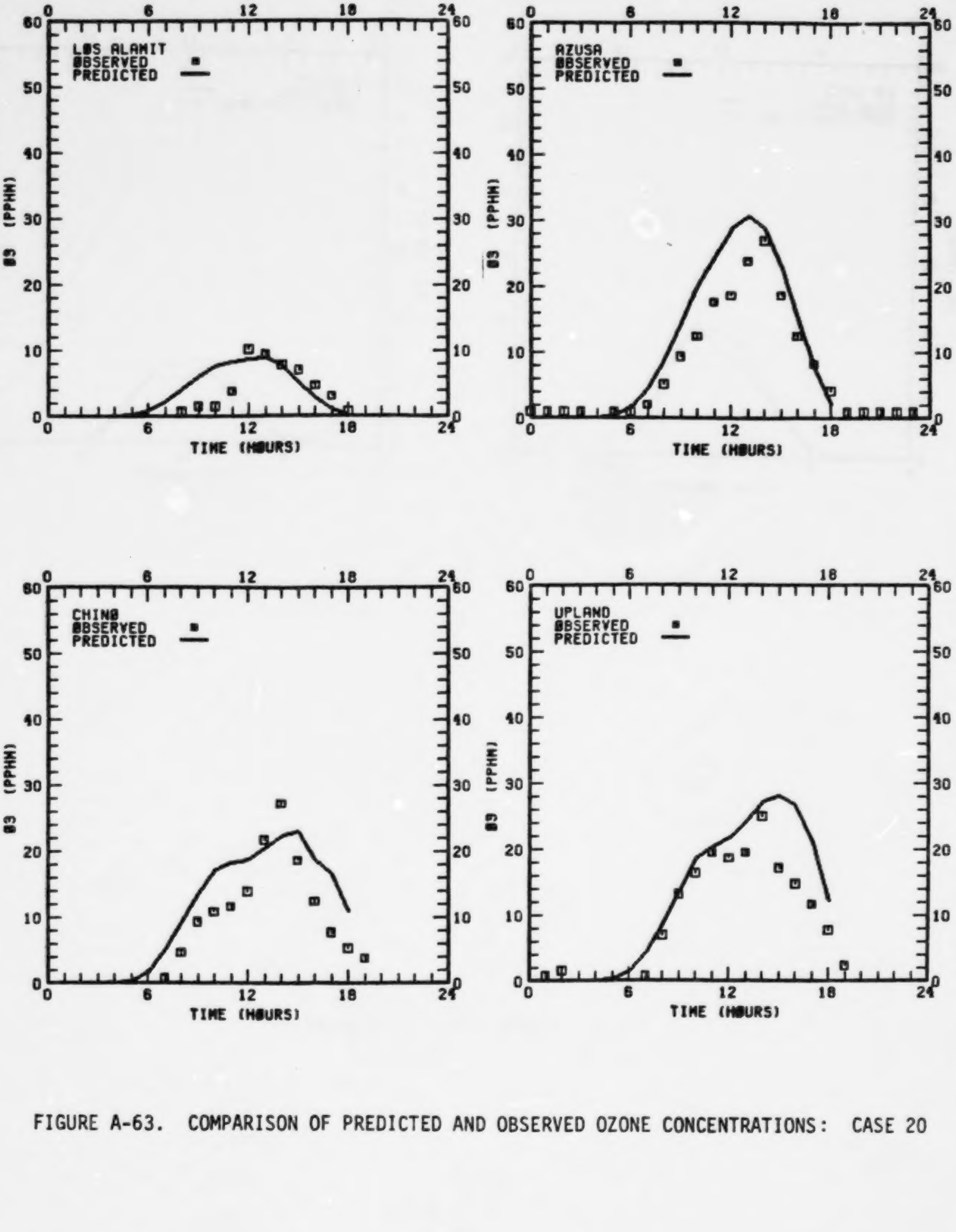

FIGURE A-63. COMPARISON OF PREDICTED AND OBSERVED OZONE CONCENTRATIONS: CASE 20

1) General Sensitivity Measures

Some measures of the general sensitivity of the model are listed in table A-27. General deviations in ozone levels are less than 6 percent. Both temporal and spatial correlations are high. There is no trend toward higher or lower concentrations because the signed deviations are much lower than the absolute deviations.

2) Sensitivity of Model Input Variables to Input Data

The structure of the model has been modified in its vertical resolution. This affects the model input variables, such as the three-dimensional wind field and elevated emissions, as well as the solution of the continuity equations for chemical species.

3) Sensitivity of Ozone Levels to Grid Vertical Resolution

Isopleths of maximum ozone deviation are shown in figure A-64, and ozone profiles at eight air quality monitoring stations are presented in figure A-65. Deviations from the base case are the largest in mid basin (e.g., La Habra and Lynwood) and at Pasadena.

As a result of the vertical averaging of chemical species concentration, the concentrations field is smoother, and this appears in the ground level ozone concentrations. It appears in figure A-65, for the stations at Chino and Riverside.

4) Conclusions

The model is not very sensitive to the reduction of the number of grid cell layers from four to two. The computational cost is reduced since only half the number of continuity equations has to be solved. This may be an interesting simplification of the model.

v. Model Sensitivity to Grid Vertical Resolution (One Grid Layer)--Simulation of 26 June 1974

The number of grid cell layers has been reduced in this study from four to one. The single grid cell layer is located below the base of the inversion layer.

TABLE A-27. GENERAL SENSITIVITY MEASURES--CASE 21

(a) General Ozone Level Deviations

	Station Statistics		Grid Statistics	
Sensitivity Measure	O_3 > 12 pphm	O_3 > 20 pphm	O_3 > 12 pphm	O_3 > 20 pphm
Signed deviation	-0.007	0.006	-0.011	-0.000
Absolute deviation	0.053	0.033	0.055	0.041
Temporal correlation	0.975	0.989	0.975	0.981
Spatial correlation	0.972	0.982	0.965	0.949

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	1.019	1.020
Peak level (pphm):		
Sensitivity case	36.1	39.6
Base case	35.5	38.9
Corresponding locations:		
Sensitivity case	Azusa	19 - 15
Base case	Azusa	33 - 14

TABLE A-27 (Concluded)

(c) Maximum Ozone Statistics

	All Stations	Downwind Stations
Peak level normalized difference	0.055	0.043
Peak time lag (hrs)	0.22	0.25

(d) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
0.0425	10,425	10,000

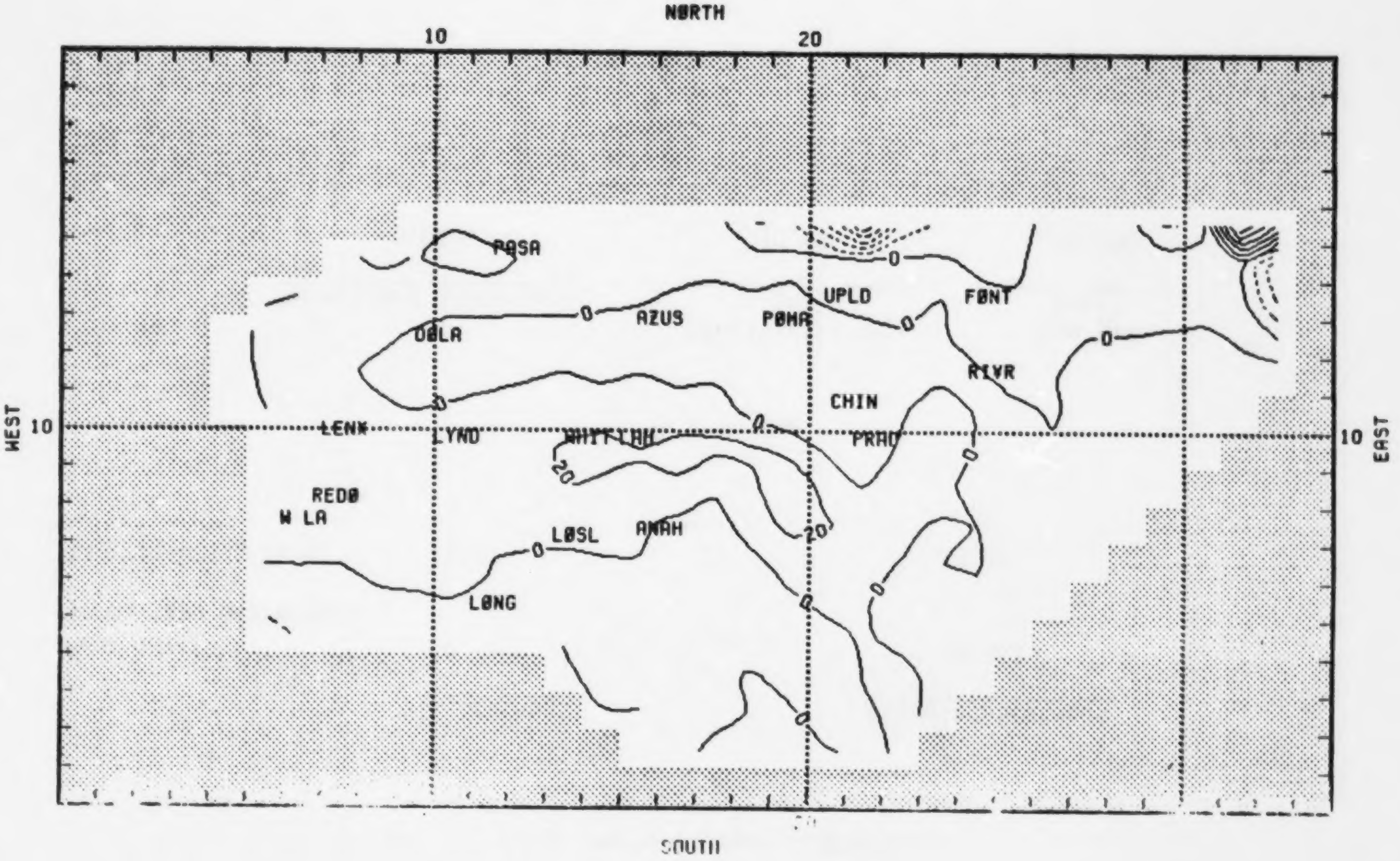
NORTH
10
20
WEST
10
EAST
10
SOUTH
20
PASA
UPLD
FONT
AZUS
POMA
DOLA
RIVR
CHIN
LENX
LYND
WHIT
LAH
PRAD
REDO
W LA
LOSL
ANAH
LONG
0
20

FIGURE A-64. DEVIATION OF MAXIMUM OZONE CONCENTRATIONS (ppb): CASE 21--BASE CASE BETWEEN THE HOURS OF 4 AND 19 LST

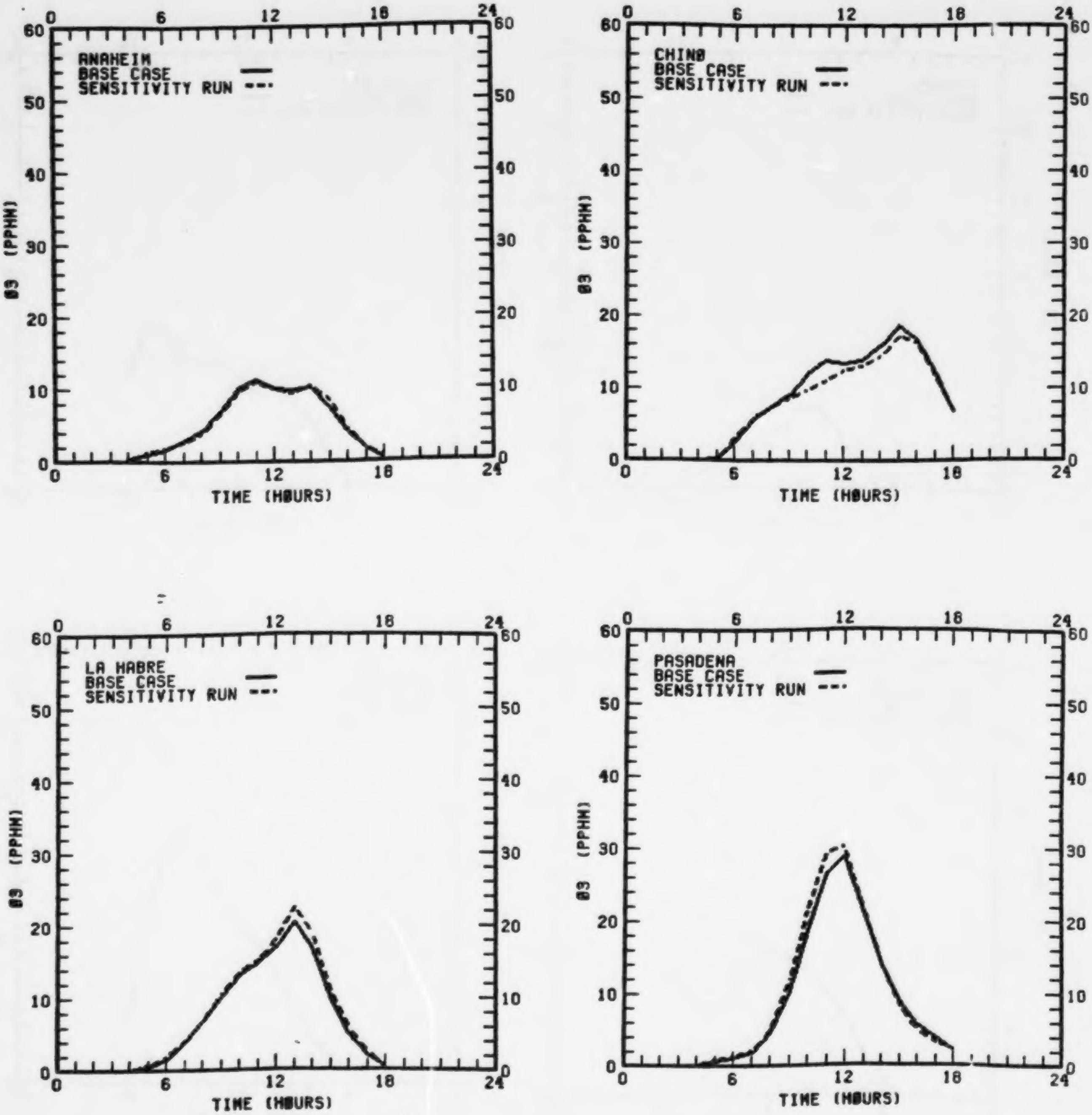

FIGURE A-65. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 21

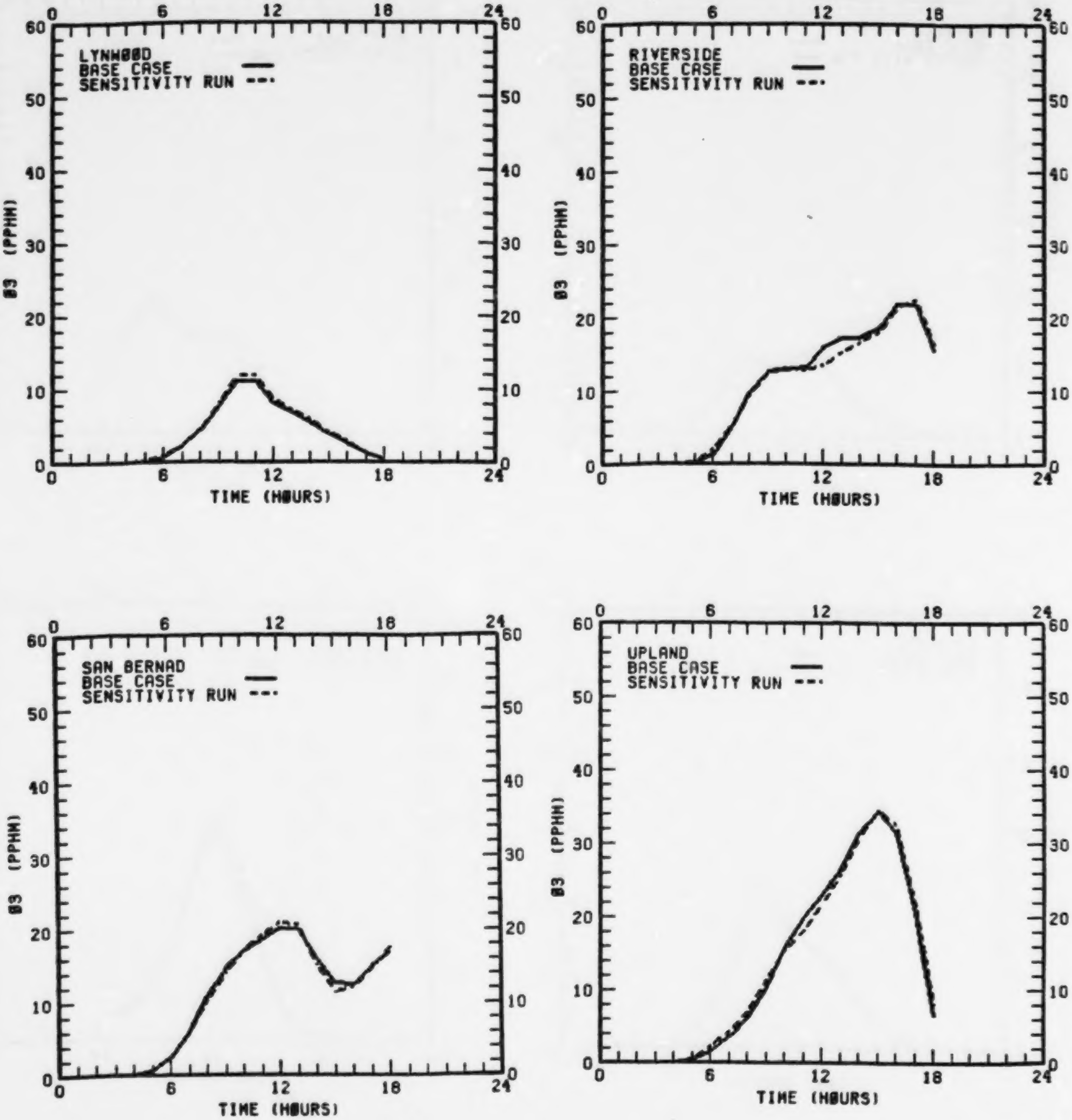

FIGURE A-65 (Concluded)

1) General Sensitivity Measures

Some measures of the general sensitivity of the model are listed in table A-28. General deviations in ozone levels are fairly high, ranging from 16 to 38 percent. There is a slight trend towards lower predicted ozone levels when compared with the base case. The two-layer model showed much less deviation from the base case, with a general deviation in ozone levels of less than 6 percent.

The temporal and spatial ozone concentration profiles appear to be fairly perturbed according to the low value of the temporal and spatial correlations.

The overall maximum ozone level is not notably affected. The dosage is a more sensitive measure, since it is increased by about 15 percent. This is in agreement with the ozone level deviation for grid statistics, which is on the order of 20 percent for ozone levels above 12 pphm.

2) Sensitivity of Model Input Variables to Input Data

The gridded structure of the model has been modified in its vertical resolution. This affects some model input variables such as the three-dimensional wind field, elevated emissions, and boundary conditions aloft.

3) Sensitivity of Ozone Levels to Grid Vertical Resolution

Ozone profiles at ten air quality monitoring stations are presented in figure A-66. Larger deviations are observed at stations near the coast (e.g., La Habra, Long Beach, Los Alamitos, and Anaheim). Very large deviations in the ozone peak levels are observed at these stations, e.g., 28 pphm in the sensitivity case versus 12 pphm in the base case at Anaheim, and 24 pphm in the sensitivity case versus 8 pphm in the base case at Long Beach. These deviations explain the higher value of the dosage in the sensitivity case when compared with the base case value.

Use of a single-layer model affects the treatment of elevated emissions and this may partially explain the higher ozone levels observed in the sensitivity case. In a multiple-layer model, nitrogen oxide emissions that are injected above the mixing layer in the morning may be entrained into this layer as the mixing height increases with time during the day. The re-entrained nitric oxide may then reduce the ozone concentrations. In a one-layer model, however, these emissions are transported

TABLE A-28. GENERAL SENSITIVITY MEASURES--CASE 22*

(a) General Ozone Level Deviations

Sensitivity Measure	Station Statistics		Grid Statistics	
	$O_3 > 12$ pphm	$O_3 > 20$ pphm	$O_3 > 12$ pphm	$O_3 > 20$ pphm
Signed deviation	-0.250	-0.235	-0.067	-0.086
Absolute deviation	0.377	0.332	0.207	0.162
Temporal correlation	0.787	0.790	0.766	0.834
Spatial correlation	0.347	0.526	0.701	0.678

(b) Overall Maximum Ozone Level

	Station Statistics	Grid Statistics
Sensitivity case/ base case ratio	1.054	0.947
Peak level (pphm):		
Sensitivity case	35.5	36.8
Base case	33.6	38.9
Corresponding locations:		
Sensitivity case	Azusa	14-15
Base case	Azusa	33-14

TABLE A-28 (Concluded)

(c) Dosage

Normalized Difference	Sensitivity Case (km^2)	Base Case (km^2)
0.1525	11525	10000

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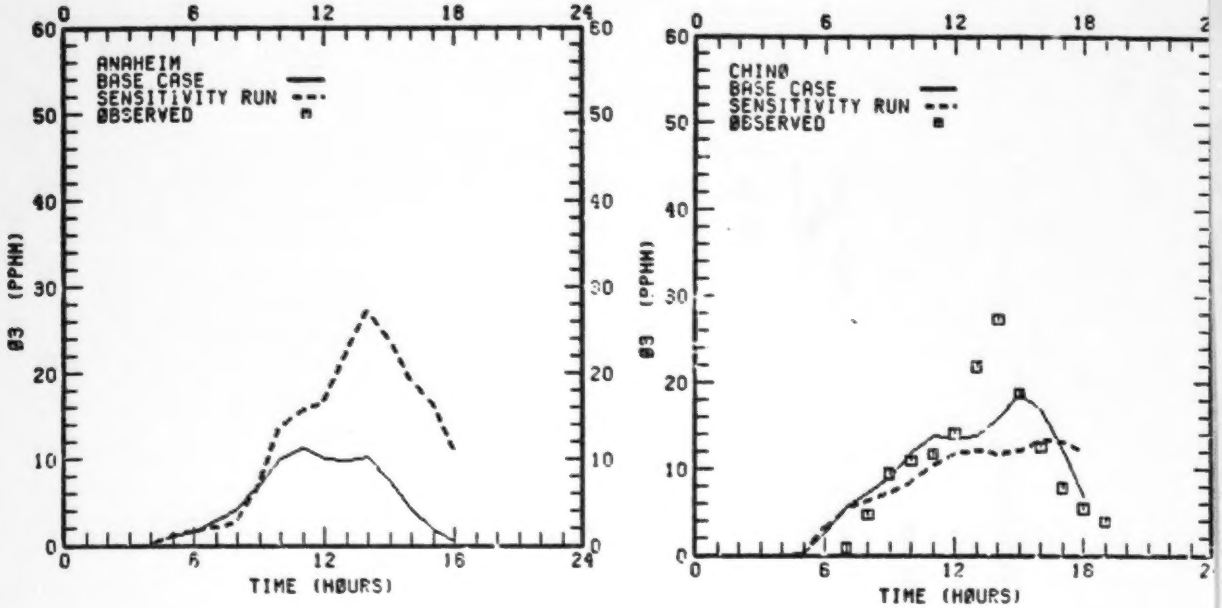
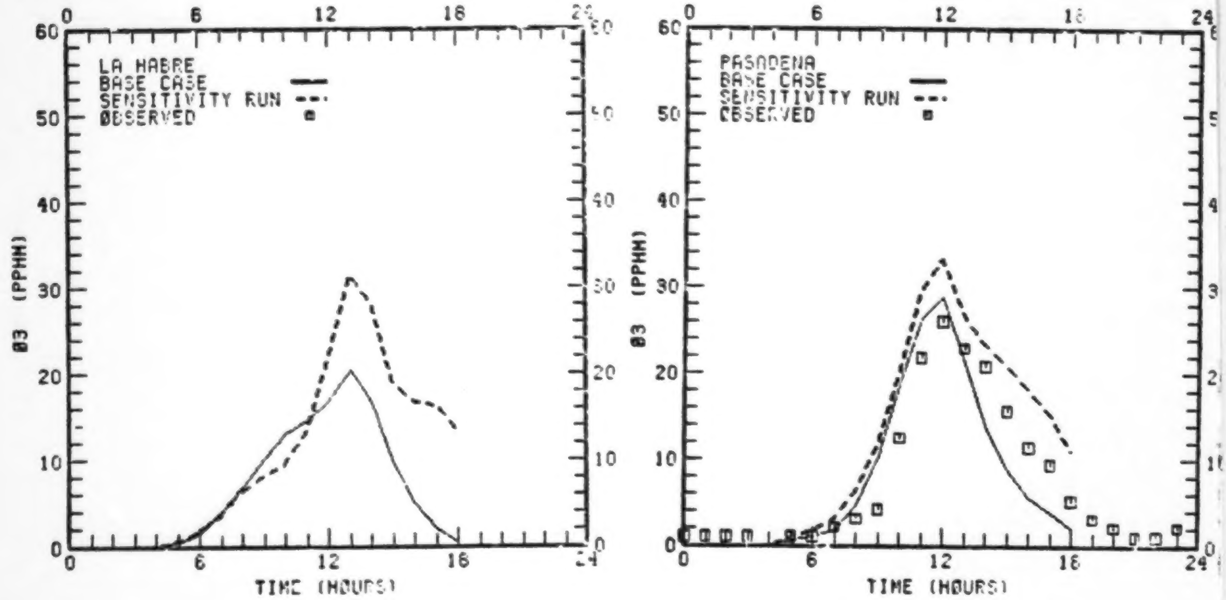
[*] Maximum ozone statistics, such as peak-level normalized difference and peak time lag averaged over several stations, were not available.

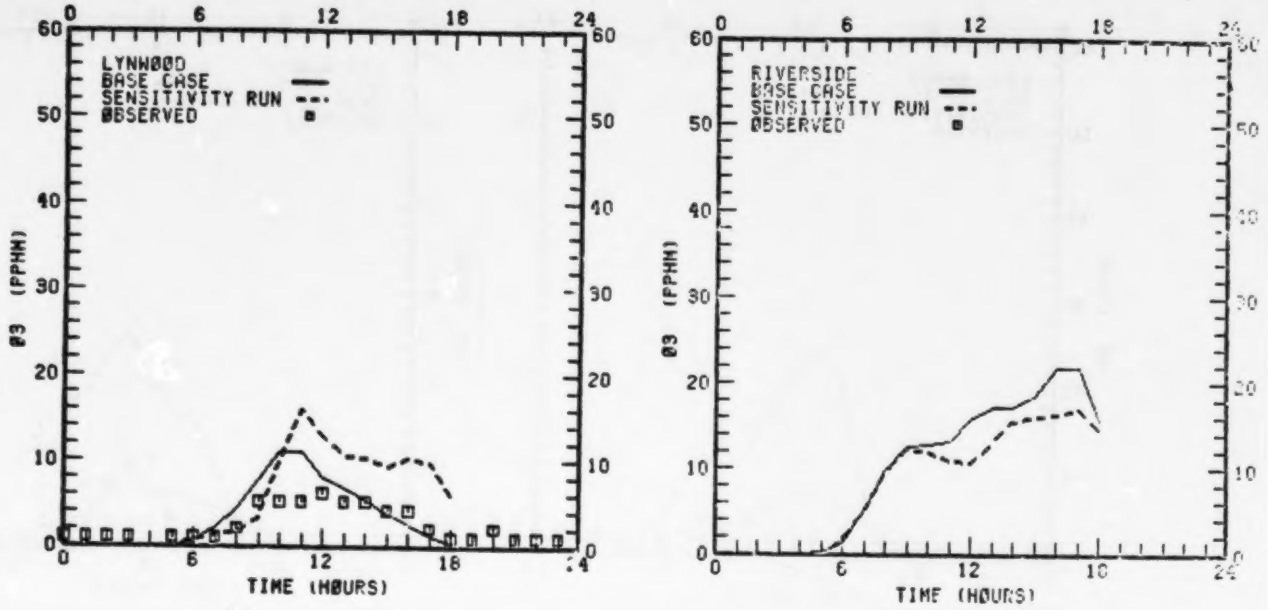


(a) Anaheim (b) Chino

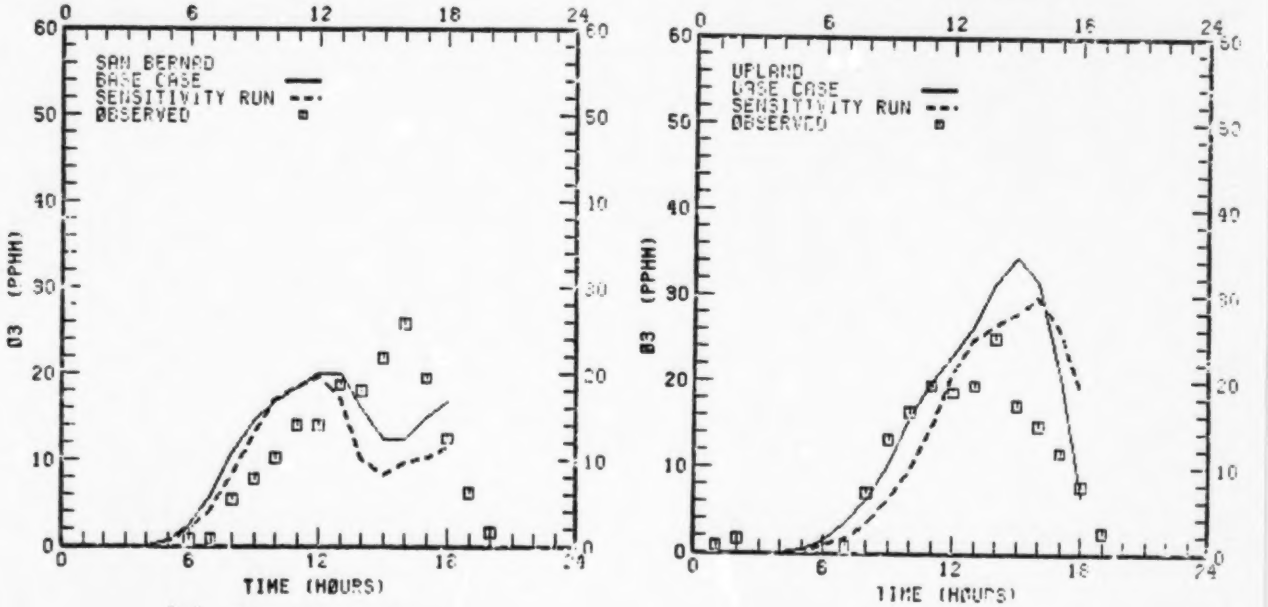


(c) La Habra (d) Pasadena

FIGURE A-66. COMPARISON OF PREDICTED OZONE CONCENTRATIONS: CASE 22

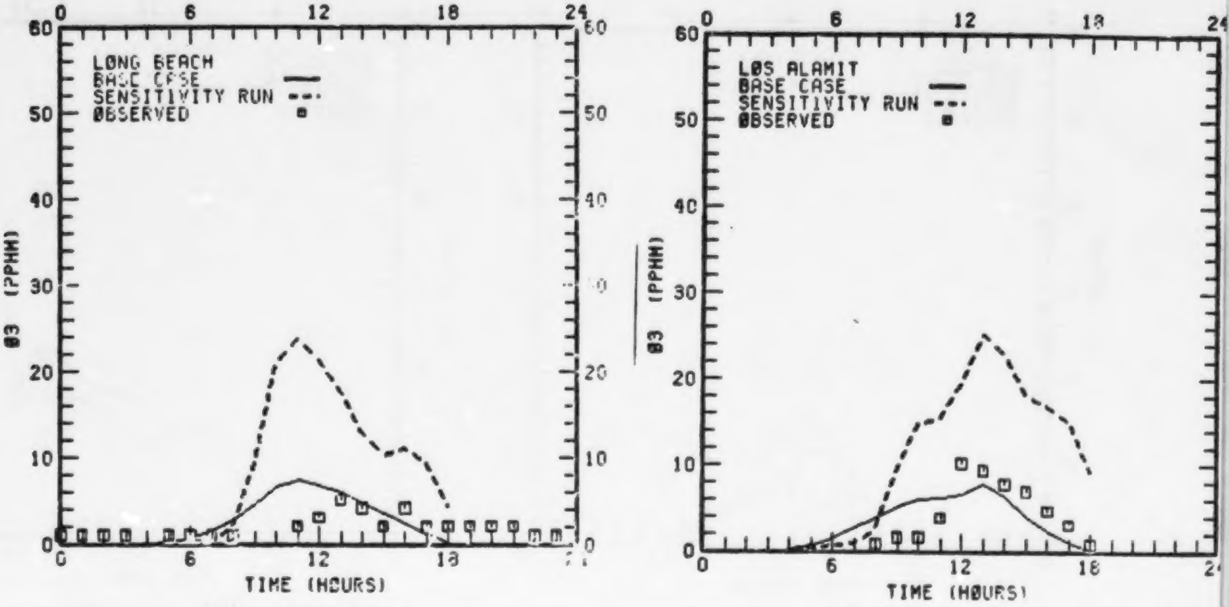


(e) Lynwood (f) Riverside



(g) San Bernardino (h) Upland

FIGURE A-66 (Continued)



(i) Long Beach (j) Los Alamitos

FIGURE A-66 (Concluded)

out of the airshed and cannot be re-entrained in the mixing layer. Thus, the nitric oxide emissions entrained above the mixing layer are not available for later scavenging of ambient ozone.

4) Conclusions

The model is sensitive to the use of a single grid cell layer. The temporal variation of the mixing height affects the chemical composition of the mixing layer through the entrainment of species from aloft into the mixing layer. This dynamic behavior of the mixing height may have some notable effect on ozone formation; therefore, from this sensitivity study, it appears important to consider at least two grid cell layers in an airshed model--one for the mixing layer and one for the inversion layer.

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